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TITLE: THERMAL ENERGY DISTRIBUTION SYSTEM

Field of the invention

Thermal energy systems, typically in the form of networks of conduits forming part of a district heating and / or district cooling system supplying a few, or more commonly, many buildings with heat and / or cold for space heating / cooling, as well as hot service water inside buildings.

Background of the invention

In a number of countries, district heating (in the UK sometimes termed: 'community heating') systems for many years have expanded successfully; in many cases, district heating comprises heating services to a majority of all buildings.. In later years, a number of district cooling systems, for air conditioning and other cooling services inside buildings, have been built as well, often alongside with existing district heating systems. In this patent application, the term: 'thermal energy distribution systems' will be used, to stress the generality of the invention. As will become apparent, the invention can be adapted to pure district heating systems, to pure district cooling systems, and to combinations of the two types of system.

Usually one or more heated or cooled, pressurised water fluid flows are maintained inside channels of conduits, mainly installed underground to form networks. Heat exchange equipment is often installed inside buildings connected to the networks, but sometimes hydronic space heating systems are connected directly to the network, to save equipment and to avoid temperature losses across heat exchange surfaces. Hot service water can be produced centrally to be distributed to,

but is normally provided locally in the building by heating of cold drinking water, either in a heat exchanger or via a coil or some other heat transfer surface inside a hot water storage tank. Although water is by far the most common carrier of thermal energy for heating or cooling, attempts have been made to use other fluids or fluid-like flows, such as for instance ice-slurry flows for district cooling.

Thermal energy distribution systems tend to be costly and time consuming to install and may cause inconvenience to traffic during underground installation, especially in centres of cities. In built-up areas of relatively low heat / cold load density (amount of thermal services per square unit of land), for instance areas dominated by single-family houses, specific installation costs (costs per unit of heat / cold connected load) tend to be rather high, sometimes making thermal energy distribution less competitive when there is an alternative solution to the heating / cooling problem, such as for instance a local boiler inside the building.

Therefore, much work has been invested into developing distribution systems with as a high a degree of pre-fabrication as possible. The introduction some 30 years ago of pre-insulated, plastic shield pipe systems represents a major step forward in this direction.

In areas of low thermal load density, and elsewhere, where relatively small cross-sections of conduits are applicable, flexible conduits are nowadays often used instead of stiff conduits. One of the advantages of flexible conduits is that they can be supplied in great lengths, to be rolled out from a spool onsite, avoiding a lot of joints, compensators and other piping elements. Another attractive feature is that flexible pipes can rather easily be adapted to follow

curved lines, for instance to circumvent obstacles (trees of gardens, for instance) on their way through the landscape. A third attraction with flexible pipes is that they, as flexible electrical cables, optical cables, etc., are more adapted to speedy installation underground, such as horisontal drilling of holes or automated processes for trenching, such as e.g. illustrated by the machine disclosed in US 6,651,361.

Still, installation of thermal energy distribution conduits calls for quite an amount of on-site work, for instance caused by the necessity of establishing branching by T-elements at many points of a network, such as where service pipes lead up to buildings.

A particularly problematic case can arise when at some later stage of network expansion there is a wish to connect an extra building, already situated or new-built amongst already connected buildings. An energy company would usually welcome such a situation, since a new customer will become a contributor to amortisation of investments already made, and the relative size of heat losses vs. heat deliveries will decrease. On the other hand, connecting new service pipes to an existing network usually is more demanding in terms of in-situ work for T-branching, breaking up existing pavements, etc. Special techniques for establishing a branching on an existing network conduit have indeed been invented, but the result is not always satisfactory. Sometimes blind T-branching elements are installed from the beginning, to facilitate later connections, but there is an added first cost associated with this, and such branching elements do not necessarily turn out to have been located optimally.

Another problematic issue, especially with single-family houses connected to thermal energy systems, is metering of heat and / or cold supplies. Although much

advance has been made in metering technology, for instance by the introduction and refinement of ultrasonic flow meters, metering of thermal services is generally significantly less accurate than metering supplies of electric energy, and meters need regular checks, which is rather time consuming, due to the substantial amount of manual work being involved in this. In the case of bigger buildings, when there is a need for personnel of the energy company to get access to meters or other network equipment inside the building, there will usually be a caretaker with whom appointment can be made for access during day-time hours. But in the case of single-family houses, often nobody is at home in daytime hours. A solution can be to install meters in a casing outside the building, to be opened by a key; but such a casing will not always be appreciated from an architectural point of view.

Purpose of the invention

The purpose of the invention is to develop a new kind of thermal energy distribution system which:

* Increases the degree of pre-fabrication of conduits further from what has been achieved by state-of-the art technology and thereby reduces the need for site work, not only when installing equipment in an initial phase of system development, but also in later phases when there a need to connect further buildings arises, especially within an existing supply area,

* Speeds up installation work, which will tend to reduce first costs and reduce disturbance to traffic during installation,

* Reduces the risk of malfunction caused by deficiencies in manual work on site,

* Increases possibilities of standardisation and mass-production in pre-fabrication of conduits and other equipment,

* Reduces first costs for metering and facilitates meter reading, as well as checks of metering accuracy / reliability,

* Makes cheap and fast detection of leaks possible, thereby reducing the need for heat exchangers inside buildings,

* Is suitable for occasional or continuous, centralised control of individual building fluid flow supply, whenever such control is suitable and is in accordance with good service of customers,

- All adding up to a cheaper, more reliable system, especially when systems provide thermal energy services to buildings of low heat density areas, such as single family dwellings.

Short presentation of the invention

As a general statement it can be said that the invention utilises the potential of flexible district heating / cooling conduits a major step further from state-of-the art practice.

A key idea of the invention is to concentrate branching of network elements to a single, or a limited, number of branching stations, STA, from which flexible conduits, CON, typically of equal outer cross-section, run adjacent to each other to form an assembly of conduits extending from the branching station, each conduit leaving the assembly of conduits by a curvature, typically to proceed along a line running roughly perpendicular to the initial main direction. By using this type network configuration it becomes possible to establish an unbroken line of conduit all the way from the branching station, whereby one omits many T-branchings directly buried in the ground of a conventional pre-fabricated system.

It is true that sometimes T-branchings buried in the ground can be omitted by adopting a network topo-

logy by which a series of buildings are connected by a chain of conduits, i.e. a conduit leads up to the first building, from which a next conduit leads to the next building, etc. This is in contrast to conventional network topology in which service conduits, branching off from a main conduit, lead up to each building. The chain-type topology does not omit branchings, but they can be established inside buildings which simplifies work and omits a number of weak points, whereby joints of sleeve pipes are exposed to the ground and in-situ after-insulation has to be done at T-branchings. Such chain-typology appears especially attractive with semi-detached houses, where conduits can be installed mainly in basements of buildings. However, with fully detached houses the chain arrangement involves conduits not solely serving a given building to be installed in the ground surrounding the building. Sometimes it even becomes necessary to install conduits on private property ground owned by people who are not connected to the district heating or cooling system. This in practice can cause a lot of trouble to the energy service company. Installation of main pipes in, or in conjunction with, public roads is therefore generally preferred.

At first look some arguments seem to speak against the arrangement proposed by the invention: In comparison with an equivalent conventional network, the new type of distribution system requires a larger total length of conduits, which may tend to increase both heat and pressure losses. Also, the assembly of conduits running in parallel tends to constitute a bigger combined cross-section than an equivalent conduit of a conventional system, maintaining the same amount of fluid flow to branch out in T-connections.

But, as will be explained and exemplified in detail below, these disadvantages are more than out-

weighed by many advantages, and there is potential for limiting the increased size of the combined cross-section of conduits running parallel. In particular it will be made clear that the adoption of superinsulation, i.e. insulation involving vacuum inside insulation materials, in designs of conduits, not only opens up for the possibility of reducing heat losses, but can also be utilised for reducing the size of an assembly of co-extending conduits significantly.

As has been pointed out, T-branchings represent quite an amount of site work and are potentially weak points of a conventional system, so that replacing them by simple curvatures of conduits significantly speeds up installation and increases system reliability. The problem of connection of buildings at a later stage can be handled rather easily by drawing an extra conduit from the branching station, where hydraulical connection is established with a minimum of work to be done.

Use of more than 2- lines, for instance 4-line systems with a separate loop for central provision of hot water services in buildings, becomes less complicated in terms of on-site work on networks.

Another advantage of the invention is that the number of conduit sizes can be reduced significantly, compared to standards in state-of-the art conduit technology. This is favourable to pre- and mass-fabrication, which will lower costs.

In the branching stations, metering equipment can be concentrated, as opposed to conventional systems where metering equipment has to be installed in each building. This lowers first costs for metering, facilitates meter reading, and makes convenient on-site accuracy checks of meters possible.

In addition the invention opens up for the use of a whole array of further, innovative developments, which can roughly be divided into two sub-groups:

1. New types of conduits can be used since there is no longer a need for making T-branchings which could be problematic to design for with the particular type of conduit,

2. Leak checks and further check procedures can be performed conveniently in the branching stations.

Detailed description of the invention

Now the invention will be described in more detail by reference to a number of figures.

Fig. 1 is a simplified view from above of a first embodiment of the invention.

Fig. 2 is an (compared to fig. 1) enlarged, cross-sectional view of the first embodiment.

Fig. 3 is schematic showing the branching station of the first embodiment more in detail.

Fig. 4a is a cross-sectional view of an assembly of conduits, and a longitudinal section of a single conduit, according to a second embodiment of the invention.

Fig. 4b is an enlarged view of a detail of the second embodiment

Fig. 5a is a cross-sectional view of of an assembly of conduits according to a third embodiment of the invention.

Fig. 5b is an enlarged, cross-sectional view of a single conduit of the third embodiment.

Fig. 6 is a cross-sectional view of a fourth embodiment of the invention, being the first of several examples of how super-insulators can be integrated into conduit design.

Fig. 7 is a cross-sectional view of a single conduit according to a fifth embodiment of the invention.

Fig. 8a is a cross-sectional view of a single conduit according to a sixth embodiment of the invention.

Fig. 8b is a schematic of a 2-line system, supplemented by a vacuum line, according to the sixth embodiment.

Fig. 9 is a schematic of a less common, but per se known type of 2-line system, which can be incorporated into the invention according to a seventh embodiment.

Fig. 10 is a schematic of a 4-line system according to an eighth embodiment of the invention.

Fig. 11 is a drawing of a branching element according to any embodiment of the invention.

Fig. 12 is a cross-sectional view of a ninth embodiment of the invention.

Fig. 13a is a cross-sectional view of a tenth embodiment of the invention.

Fig. 13b is an enlargement of one conduit of the tenth embodiment.

Fig. 14 is a longitudinal sectional view from above of the tenth embodiment.

Fig. 15 is a longitudinal sectional view of an eleventh embodiment of the invention.

Fig. 16 is a view from above of the eleventh embodiment.

Figs. 17a-c are three cross-sectional views of the eleventh embodiment.

Figs. 1, 2, and 3 together show a first embodiment of the invention. Fig. 1 is a top view, for simplicity showing each conduit, CON / CON*, schematically as a single line, although, as shown in the sectional view given in fig. 2, each conduit comprises 2 channels, CHA, one being part of a forward line sending out fluid (typically pressurised water) flow to the building, BUILD, in question, the other line returning flow from the building. The channels are surrounded by heat insu-

lating material, INS, typically contained within an outer shield pipe (here squared). Fig. 3 shows how the per se known, closed loop type 2-line system is incorporated into the first embodiment and gives a more detailed, schematic view of the branching station, STA, including metering equipment, as well as monitoring equipment inside the building

Fig. 1 shows a hierarchical system, in which the connection principle of the invention (as an example) has been utilised on two levels: The lowest level, in which all conduits lead up to buildings, is reprented by the distribution system at the top, termed DISTR. Below, there are two more distribution systems at this level. From each lowest-level distribution system conduits, CON (and CONBIG) branch out from a branching element, BRA, inside a branching station, STA. At the next hierarchical level, distribution system DISTR*, conduits CON* branch out from a fourth branching station, STA*. Three of these conduits extend to the lower-order branching stations, STA, whereas a single conduit, CONBIG* extends to a single, big building, BUILDBIG*. All buildings, BUILD, could be single-family dwellings, while the two bigger buildings, BUILDBIG and BUILDBIG* could be multifamily buildings, office buildings, a school, etc. Inside branching stations, BRA, distribution systems, DISTR1 ..., are connected to the higher-order level system, DISTR*, via heat exchangers, HE.

The detailed geometry adoped in fig. 1 is a little schematic and more regular than will typically be found in practice. One of the deviations from the regularity is that all conduits in DISTR are shown to bend by an S-like curvature close to the branching station, STA, where they are arranged adjacent to each other. Each conduit CON is composed of three parts: A first part,

CONa, arranged adjacent to other conduits, a small curved, second part, CONb, leading the conduit away from the other conduits, and a third part, CONc, running roughly perpendicular to CONa and up to the building, BUILD, in question.

As an example, fig. 2 shows that conduits can be arranged directly underground (claim 2) and can be made of an outer, squared shape, with rounded edges, to make the conduit less sensitive when transported to the site and when being laid or drawn underground during installation. The squared shape minimises voids between conduits, which maximises the amount of heat insulating material. In order that unwanted heat exchange with the surrounding soil be minimised, in each of the 8 conduits in contact with surrounding soil, the channel providing part of the forward, F, line (carrying relatively high-temperature fluid) is arranged farther from the envelope of the assembly than is the channel providing part of the return, R, line.

All 9 conduits are of the same outer shape and dimensions; 8 conduits are in addition of identical cross-section, while the centre conduit, CONBIG has channels of bigger diameter, this conduit carrying a bigger flow rate to BUILDBIG. In spite of the slightly differing central conduit, system DISTR displays much more standardisation of conduit sizes than what would be found in most corresponding distribution systems of a conventional design.

Each conduit has the same cross-section all the way from the branching station, STA, to the building, BUILD, in question. The conduits are flexible, which is used for creating curved parts CONb of conduits, where they leave the other conduits, but can also be used for making bendings of conduit parts CONa and CONc, e.g. to

circumvent obstacles in the landscape, as is commonly done with flexible conduits according to prior art.

DISTR1 can be a conventional thermal energy distribution system or it could be a further distribution system according to the invention, where conduits lead up to, either branching stations, STA*, or to a combination of one or more branching stations and one or more bigger buildings.

In the conduits shown in fig. 2 one or more signal CABLE(s) has / have been integrated into each of the conduits. This is a possible facility, not a provision for, the invention. The idea of equipping a DH conduit with a signal cable, by which communication with internal systems of the building becomes possible, is not per se new. As such the idea of 'splitting' costs for digging and laying of conduits and cables lies close at hand. However, with the configuration of the invention, avoiding branchings of conduits from the branching station to the buildings, it becomes particularly easy to employ this idea. Also, as will be explained below, it provides possibilities for extremely reliable and detailed metering, along with possibilities for extended system surveillance.

Fig. 3 shows an example of a connection scheme, from the branching station, STA, of fig. 1 to and including the connected buildings with their internal distribution systems and a local temperature recording unit providing information to the building owner and collecting signals for centralised handling in the branching station.

In accordance with the conduits shown in fig. 2, fig. 3 shows a (closed-loop), branched 2-line system, comprising a forward line, F, and a return line, R, respectively, providing space heating and hot service water, HW, being incorporated into the invention. For

simplicity, only the internal distribution systems of one building, BUILD, has been drawn, and a single radiator, RAD, and a single hot water faucet, FAC, have been shown, to represent the normally greater number of such elements inside each building. Hot water, HW is produced from cold water, CW, in a heat exchanger HE1 inside the building, the HW distribution temperature being determined by a thermostatic valve control, THW. District heating water from the forward line, F, is led directly into the hydronic distribution system for space heating, the room temperatures being controlled by thermostatic valves, THR, fitted to each radiator, RAD.

As a general comment to fig. 3 it can be said that quite a lot of transducers, valves, and signal transmission facilities in the figure have been adopted in the figure. This has been done in order to illustrate a multitude of facilities which can be adopted with the invention. As will be understood, various of these facilities could very well be left out in particular applications, depending on various priorities. Thus, a particular system in practice may appear simpler than the one shown in fig. 3. One example of a simplification would be to dispense with CABLE(s).

A central pump, PU, inside the branching station, STA, can maintain circulation in all 9 individual building heating loops, when needed. An expansion tank, EXP, controls return line pressure and allows for thermal expansion and contraction of circulating water volume. Heat insulation (not shown in fig. 3) should be applied to all pipes, heat exchanger, etc. inside the branching station, to minimise unwanted heat transfer with the surroundings and heat transfer between individual system elements operating at differing temperature.

Inside the branching station, branched lines, BRAL, are connected to channels, CHA, of the forward, F, and return, R, lines leading flow to and from each building. These branched lines are inside STA shown to be equipped with flow meters, FM1´and FM1´´ and with temperature sensors, TS1´ and TS1´´, all communicating measured values to a signal handling equipment unit, SIG. These values can be measured on an instantaneous value basis or on the basis of a sampling time values. In addition to meters / sensors, the return branched lines leading flow to the branching element, BRA, are equipped with valves, VA1, ... whose position can be controlled from SIG. The first embodiment of the invention, by example of fig. 3, shows a branching station capable of performing several metering and check procedures, as will be explained. Again, If one or more of these facilities is / are not wanted, one or more of the elements just mentioned can be left out to simplify the station.

The ambient temperature, TA, is being recorded by SIG; thereby SIG can adjust the supply temperature TS', such that this temperature is raised above a minimum level when the ambient temperature TA falls below a certain level, say 0°C. As an overall check that substantial amounts are not lost by any leakage of the closed-loop circuit, a LEVEL indication from the expansion tank, EXP, is transferred to the signal handling unit SIG.

Sometimes district heating supplied to a customer is accounted on the simple basis of the amount of flow sent to and returned from the building in question, irrespective of temperature levels. In that case, either flow meter FM1´ or FM1´´ can be used for registration, for instance of the total amount of flow circulated in each quarter of the yearly season. More often, though,

accounting is made on the basis of the amount of energy supplied. In that case, temperature sensors TS1´ and TS1´´ in combination with either flow meter FM1´ or FM1´´ can be used. The signal handling equipment in a known way can be equipped with calculation procedures for compensating for temperature dependence of water density and specific heat.

According to the invention, and in contrast to conventional district heating / cooling systems, some or all metering of services to individual buildings is concentrated to branching stations, instead of being provided for inside or close to each building. Concentrating metering equipment to the branching station has a number of advantages:

A single signal handling unit, SIG, replaces individual signal handling units inside each building. This reduces first costs and allows for more advanced and reliable equipment to be chosen for this unit. Also, one might dispense with individual thermal sensors, TS1´ ... TS9´, since all should register essentially the same temperature, and replace them by a single, central sensor, for instance TS´ adjacent to the central heat exchanger, HE, in fig. 3.

Access to meters and sensors for reading, checking, and replacement becomes easier, in particular in the case of single-family houses, whose inhabitants may not be at home in daytime hours to give energy company personnel access to their house.

First costs for meters and sensors can be lowered for several reasons: Fabrication costs of meters can be lowered, since measurement equipment can be built into a common mechanical unit. This will also significantly simplify exchange of meters and sensors for calibration in a laboratory rig, since all meters and sensor can then be taken out and replaced by a whole new assembly

of meters and sensors, instead of such replacement work being done individually in each building. Also, due to better possibilities of checking meters, as will explained below, it may be permissible to opt for cheaper types of meters and sensors for the individual metering.

Effects of individual installation geometries on measurement accuracy can be eliminated / reduced significantly: Flow meters and temperature sensors are known to be more or less susceptible to individual geometries of installation and surrounding piping. For instance, a bend may cause a distorted velocity profile within the pipe leading up to a flow meter inside a building, which will cause a measurement error. Accordingly, flow meter installation is usually made subject to requirements for certain minimum up- and downstream lengths of straight pipes (usually specified in terms of number of pipe diameters). Temperature sensors are required to be installed in ways that will reduce measurement errors due to heat losses and / or thermal stratification within the fluid. But space is not always available for long, straight pipes, and even when in a certain buildings conditions are favourable for correct installation of meters and sensors, less careful in-situ work may result in unnecessary measurement errors due to installation effects. When instead, as shown in fig. 3, individual meters and sensors are installed in a branching station, the design can be made, in a standardised way, applying to many stations to reduce installation effects, and remaining installation effects can to a certain extent be eliminated by calibrating meters and sensors when situated exactly as in the branching station; this will be explained more in detail below, in relation to the example of fig. 11.

On-line and other check procedures can be adopted in various ways to check the accuracy of meters and sensors installed in the branching station: For instance, if a flow meter is installed both in the forward line, FM1´, and in the return line, FM1´´, as exemplified in fig. 3, and given there is no leakage in the flow route from FM1´ to FM1´´, they should read the same mass flowrate.

Another kind of check possibility is provided if equipment is installed for measurement of overall flowrate (FM´ and / or FM´´) and / or overall thermal energy rate. In the example of fig. 3, supplied thermal energy rate can be registered by combining values read by temperature sensors TS´ and TS´´ with the flow rate measured by one of the flow meters, FM´ and FM´´. Such a registered overall flow rate and overall thermal energy can be compared with summed values recorded for individual supplies to buildings, and the size of any deviation will provide an evaluation of the reliability of the registered values. According to fig. 3, overall thermal energy rate is measured on the secondary side of the central heat exchanger, HE, inside branching station, STA. Another possibility is to make measurement on the primary side of the heat exchanger, which should give identical values, provided heat losses from the heat exchanger and pipes can be considered negligible, and no flow leakage occurs across the heat exchanger surface.

When overall flow rate and central temperatures are measured in addition to individual values for each building, there is the possibility to choose rather sophisticated and carefully calibrated equipment for measurement of overall values, and cheaper, less accurate equipment (but not necessarily equipment more susceptible to failure) for individual measurements. This

can bring down the total cost for measurements. When such a strategy is used, there is the possibility to divide a deviation registered in the checking procedure among individual readings, for instance on a pro rata basis, as a correction towards values that are probably closer to true values. Such a procedure can be combined with an alarm criterion that draws attention to a deviation value exceeding a pre-set limit of acceptance, to prompt an individual action, such as taking the assembly of measurement equipment out for laboratory checking. Naturally, such an alarm criterion will not provide a fail-safe guard against the risk that two or more gross errors happen to more or less cancel out each other. Thus, laboratory calibration of equipment on a regular basis cannot be dispensed with completely, but since check procedures like the ones described will reduce the risk of component failure, they could be taken advantage of to accept longer intervals between laboratory calibrations; this will help bring down costs for metering.

According to fig. 3 a local status collection and display unit, STAT, in each building collects a number of temperature recordings, for visual display to the building owner, and for further transmission to the central signal handling unit, SIG, via signal CABLE(s). When this is done it becomes natural to base calculations of delivered amounts of heat on the basis of, not centrally measured supply and return temperatures, TS1' and TS1'', respectively, but on the basis of the locally measured values, TS1''' and TS1''''; thereby heat losses between the branching station, STA, and the individual building is accounted for. Even if conduits do not comprise any CABLE(s), transmission of locally recorded fluid temperatures may be possible, e.g via the telephone network.

If there is/are no signal transmission facility, one would use the centrally recorded, individual building temperature signals, TS1' and TS1''. This raises the issue of taking calculated or estimated heat loss values into account in some appropriate way.

In an extended system (with CABLE(s)) like the one shown in fig. 3, even though temperature reading in each building there are significant advantages associated with moving individual flow metering away from the building to centralised measurement inside the branching station, as will become apparent by the example of fig. 11 here below. Sensing supply and return temperatures both at STA and at BUILD provides a possibility of keeping check on individual heat losses in conduits CON, which can be used for fast detection of various defects that might arise.

Recording and displaying all the temperatures as shown in fig. 3 also provides possibilities for various types of checks that may be useful to the customer. For instance, a satisfactorily high primary water temperature, TS1''', but a too low hot water temperature, THW, may indicate excessive heat exchanger fouling. Observing this will help prevent hot water temperatures that may represent lowered comfort level or even a risk of multiplication of the dangerous Legionella bacterium.

In fig. 3 inside the branching station is shown a valve, VA1, fitted into the return line from the first building. This valve can be used for several purposes:

As has been noted, in the first embodiment of the invention illustrated in fig. 3, hydronic space heating systems of buildings are connected directly to the local distribution system, DISTR, i.e. for this service there is no heat exchanger to provide hydraulical separation. Some energy companies hesitate to dispense with such a further heat exchanger for various reasons. One

argument is that, in case of a leaking radiator, a heat exchanger separating the hydronic system from the district heating network will maximise to the potential amount of water leakage to the water volume of the hydranic system, not the volume of the district heating system, which will usually be much bigger. As a precaution against the risk of a greater leak in case of direct connection, valve VA1 can be used for leak detection: By closing the valve and measuring the flow rate in the forward line by flow meter FM1´ any leak can be detected, provided the flow meter is capable of measuring relatively small flow rates, and measurement is made on a continuous basis, so that any transients attributable to thermal / pressure driven expansion / contraction of the loop can be assumed to have died out. Instead of a flow meter, temperature recordings can be used to check against leaks, since in a tight loop closed off by a valve, water will cool off, due to heat losses.

When both the forward and the return lines are equipped with flow meters, FM1' and FM1'', as in fig. 3, the difference between the mass flow rates registered by the two flow meters constitutes a further, online, possibility of detecting at least a major leak which would result in a difference exceeding any difference that could be attributable to inaccuracy in flow measurements.

Another possibility provided by individual valves, VA1..., inserted into loops serving buildings, is to centrally control individual fluid flow rates and thermal energy supply to buildings (claim 27). In normal operation an energy company will allow local control equipment inside each building to decide the appropriate amount of flow supplied to any building. But on rare occasions, it can be in the general interest of

customers if the energy company has the capacity to exercise control on individual supplies. Such occasions may be when, for some reason, there is a general shortage of thermal energy supply, because of an exceptionally low outside air temperature, or a breakdown of generating plant. In a conventional district heating or cooling system, due to higher differential pressure between forward and return lines, such a shortage of supply will hit customers unevenly: Buildings located close to circulation pumps may experience no shortage at all, while other buildings, typically those in the periphery of the distribution system, may suffer a more or less complete stop of supply. By resorting to a centralised control, throttling a little on all flow supplies the energy company can avoid such a situation.

A hierarchical system according to fig. 1 would typically be a beneficial arrangement with conduit designs with relatively small outer dimensions for a given energy rate transferred, so that the size of the outer envelope of conduits CON* extending from STA* will not be too large, and extensive use is being made of flexible conduits, saving time and money when installing conduits underground.

Although, as shown in fig. 1, the number of conduits extending from different branching stations, STA, may differ, a standardised, modularised branching station design can be adopted. For instance, differing stations may share a common outer shell design, which will lower costs. Fig. 11 below will show how metering associated with a branching element can be made in a both sophisticated and rationalised way.

Fig. 4a shows a combined cross-sectional and longitudinal sectional view of a second embodiment of the invention. Here, the outer shape of the thermally insulated (INS) conduits is sexangular, and conduit parts

CONa are arranged to be surrounded by thermally insulating material, INSa, inside a common casing, CASa, as opposed to fig. 2 where conduits are placed directly in the ground. This casing may be essentially stiff, if it is appropriate that it follows a straight line, or the casing my be elastically or plastically deformable, when (such as demonstrated in fig. 1) the assembly of first conduit parts, CONa, is supposed to follow a line being wholly or partly curved.

The casing is provided with one or more openings where individual conduits depart from the conduit assembly. Such an opening can take the shape of individual holes, or the entire casing may have a cross-sectional shape of a circular arc not extending all 360 degrees round; this type of design makes later arrangement of extra conduits easier.

As shown in fig. 4, a conduit part CONc (and sometimes in addition curved part CONb) can also be arranged to be surrounded by thermally insulating material, INSc, either arranged directly in the soil or, as shown in fig. 4, inside a casing, CASc. When extra heat insulation, such as INSa and INSc, is added, as shown in fig. 4, the outer dimensions of conduits can be chosen to be smaller than when the heat insulating material of the pipes (as in fig. 2) is supposed to provide virtually all heat insulation.

Fig. 4b gives an enlarged view a detail of CONc, close to the forward, F, line channel, CHA, illustrating a particularly appealing structure of the conduit: Here, the conduit is made from a single, polymeric material; an integrated polymeric structure comprises a body part with heat insulating CELLs, as well as inner (at CHA, F) and outer surface layers, SURF, which are compact and smooth, making all surfaces of the conduit mechanically robust. The smooth inner surfaces will re-

duce pressure losses of fluid flow inside the channels. The proposed polymeric structure is suitable for mass-production by use of modern fabrication methods for polymers.

In the embodiment of the invention shown in figs. 4a and b, for minimisation of heat losses, channels, CHA, providing parts of the forward line, F, are located closer to the centre of the assembly than those channels providing part of the return line, R, as in the first embodiment whose cross-section is shown in fig. 2. Fig. 4a illustrates a further possibility of reducing heat losses: Designing channels, CHA, of the forward line, F, with a smaller diameter than those of the return line, R. A bigger diameter of the return line channels has the further advantage that, due to a smaller pressure gradient along the return line, by using pressure reducing valves in forward lines at or inside buildings, BUILD, it becomes possible to operate pressurised equipment inside buildings at a relatively low pressure, when directly connected to the district heating system, i.e. when there is no hydraulical separation by heat exchangers.

If the flexibility of the conduits is of a purely or predominantly elastic nature (claim 7), and a casing CASa is used, as shown in fig. 4a, it becomes particularly easy to arrange conduits underground by drawing them inside the casing, either in the direction from the branching station, STA, or in the opposite direction. Conduit parts CONb and CONc can also be drawn inside casings, or these conduit parts can be arranged underground in a more conventional way, for instance by laying them in a channel dug out in the ground. Conduits arranged by drawing should preferable have such surface finish and may be additionally prepared in an appropriate way (claim 6), for instance by being lubri-

cated or supplemented by a smooth folio, so that they can be drawn underground without use of excessive force.

Provided sufficient space is left within casing CASa, as shown in fig. 4, extra conduits for later connection of new customer buildings to the distribution system can be added by drawing them inside the casing and by connecting them hydraulically to branching element(s) BRA of a branching station, STA. Branching elements can easily and at very low cost be prepared for this by use of blinded or valve-closed branch-off pipes, so that new conduits can be connected without interrupting thermal energy supply of already connected buildings. It is understood that in this way the invention in a convenient and robust manner facilitates later connections, avoiding the sometimes difficult establishment of branchings in previously established network parts according to prior art, as described when presenting here above the background of the invention.

Both the squared and the sexangular shape of conduits according to figs. 2 and 4a, respectively, are somewhat unusual. Instead, as the third embodiment of the invention of figs. 5a and b illustrate, commonly used shapes, such as a circle or an ellipse may be used. In fact, the whole conduit can be pre-fabricated and / or designed according to methods and designs known in prior art. This can make introduction of the invention in practice particularly easy.

Fig. 5b is an enlarged view of one of the conduits of fig. 5a. This cross-sectional view displays many features which are known from conventional, pre-fabricated, flexible district heating pipes: Inner pipes are made of copper, Cu, which is plastically deformable, and the insulation, INS, is a closed cell, flexible foam made of PEX, i.e. cross-bonded polyethylene, which

can be supplied as a relatively heat-resistant polymer. Also the outer shield pipe is made of PEX.

It can be seen that each conduit of the embodiment shown in figs. 5a and b comprises in total 4 medium carrying pipes or channels, CHA: A forward, F, and return line, R, both for carrying a space heating and / or cooling fluid, as well as a hot service water forward line, HWF, and a return water line WR of circulated water not being tapped off inside the connected building. The hot water, HW, is assumed to be prepared centrally from cold water, CW arranged to be fed in at the branching station, STA. Lines HWF and WR are shown to be arranged adjacent to each other; there is no reason for reducing heat exchange between these two lines - heat insulating material is better used for preventing heat exhange with, and between, the two other lines, F and R, as well as heat exchange with the surroundings.

As an alternative to copper, one might also use PEX for the inner pipe. Normally, water will flow inside the channels. In that case, oxygen may diffuse from the outside of the conduit and through it, to become dissolved in the water. In case the system is such designed that this water flows through corrosion susceptible components, such as steel radiators inside connected buildings, this may not be tolerable. To prevent such a problem, it is common to use metallic or polymeric folio membranes, e.g. around inner pipes carrying the water flow in question, here lines F and R, and / or to employ a membrane between the insulation and the outer shield pipe. The latter arrangement will also help prevent any diffusion of gases / vapour in and out of cells of the insulating foam, which would increase heat transfer through the insulation.

Arranging as much as 4 channels inside a conduit is per se not novel, but somewhat unusual. In conventional thermal energy distribution systems, with many T-branchings of conduits, there is a tendency that such branchings become more the difficult to design for and arrange by work in situ the more channels are comprised by each conduit. Also, if preparation must be made for T-branchings, this to some extent restricts exactly where it is appropriate to arrange channels in the cross-sectional geometry. The invention completely avoids any such difficulties or restrictions on conduit design.

Very interestingly, the invention opens up for the use of un-common or quite new types of conduits which in some cases might have been considered previously, but may have been discarded, since branching with T-s would have been too complicated. Numerous variations of new types of conduits can be thought of. One example has been shown already, i.e. the polymeric structure illustrated by fig. 4b.

Typically, in the design of conventional conduits, at least three different materials and or fabrication methods are used: For instance, there may be one or more fluid-carrying pipes of steel, copper or a heat-resistant polymer, such as PEX. Second, there will be an outer shield pipe of a polymeric material, such as high-density PEH. In-between these pipes a heat-insulating closed-cellular foam of a polymeric material, usually PUR or PEX, will be arranged.

In fig. 5a the casing has been shown to be thin - it could be a metal pipe with thin inner and outer polymeric surface layers to make it corrosion resistant.

Super-insulators constitute a class of per se known isolation arrangements of various types, whereby

an enhanced insulation effect has been achieved by using vacuum inside the insulator. Some super-insulators which have been adoped for various applications include the following:

- A multitude of radiation-reflecting, thin metal (e.g. aluminum) foils, kept apart to avoid heat conduction from layer to layer,

- Powders made up of granules (e.g. silica-gel) of a suitable (complicated) micro-shape, such that the contact surface between adjacent granules becomes very small,

- Fibrous structures, where the fibers can be predominantly oriented in parallel planes, so that the aggregate heat condution in the direction perpendicual to the direction of the planes becomes smaller.

Power / fibrous structures are sometimes mixed, and platelets of radiation reflecting metal can be added to reduce heat transmission by radiation.

Technological fields in which super-insulators have gained general acceptance include: Cryo-technology (e.g. in pipelines for transport of liquefied gases, such as nitrogen), cooling technologies (including household refrigerators), and spacecrafts. Closed-cell foams, such as polyurethane foam commonly used in DHC conduits, exhibit heat conductivity in the order of 0.030 W/mK. Superinsulators generally have conductivities below 0.010 W/mK. The most sophisticated (and expensive) superinsulators can attain a conductivity even below 0.00010 W/mK.

A basic problem in most applications is that the super-insulator and its surrounding design elements generally must be capable of transmitting force in a mechanical design. Separate design members, themselves not being superinsulators, will transmit heat in addition to force, which calls for ingeninuity in devising

the whole structure of high heat-insulating capability. In a number of applications, where low but not extremely low, heat conductivity is called for, one can select a type of super-insulator which by itself is capable of transmitting force, i.e. mainly a powderous material.

Incorporation of a super-insulator into a DHC conduit appears attractive in systems according to the network configuration of the present invention, because it will relieve an inherent difficulty of the invention, viz. that conduits conduits with conventional heat insulation and of a small inner fluid-carrying diameter must have significantly larger outer dimensions, for heat losses to become acceptable; this means that the outer envelope of the assembly of conduits extending adjacent to each other from the branching station, tends to be rather big. Superinsulators offer a possibility of keeping the ratio between inner and outer dimensions moderate, with acceptable heat losses, even in the absence of supplementary insulation members: A thin casing CASa, as shown in fig. 5a can used, and conduit parts CONb and CONc, outside casing CASa, could be disposed of altogether.

Of course, super-insulators also provide the possibility of lowering heat losses.

A few attempts have been made to use superinsulators for DHC conduits, so far without any significant success in practice. The designs adopted have mainly been for stiff conduits, whereas in the concept adopted in this invention flexible conduits are called for.

In other branches of technology, for instance in WO 01/14783 and in US2001/0035224, flexible pipes mainly intended for carrying a low-temperature fluids for superconduction of electricity, are described. In principle these designs, directly or modified, could be

used as incorporated into the present invention. They incorporate corrugated inner and outer steel pipes for attaining flexibility. Modified variants of these designs could for instance rely on smooth, flexible pipes instead of corrugated pipes.

Fig. 6 shows a cross-sectional view of a fourth embodiment of the invention in the form of a novel type of flexible conduit, incorporating super-insulating material for part of the heat insulation, a type which has been devised directly aiming at DHC applications. An inner PIPE, e.g made of PEX, surrounds a channel CHA, which could be both a forward or a return flow channel. The outermost SHELL and the insulator, INS, can be made of dense and foamy PEX, respectively. INS has an inner circulator surface, which in combination with PIPE gives an annular space. In this space, 4 flexible supports, RUB, made of rubber, are interposed, as well as 4 bags containing superinsulator material, SUP, held under vacuum. The bags can be made according to known methods in prior art, of laminated foils, to provide good barriers to any diffusion of gas or vapour from the outside, which would destroy the vacuum, as well as good mechanical strength, which in combination with powder inside the bags provide a substantially constant shape of the bags in operation. The powder can be supplemented by granules of a so-called better material which captures any molecyles that might transverse diffusion barriers, thereby helping keep up the vacuum condition of the superinsulator.

The rubber supports are compressed so that they exert radial inward forces on PIPE. The residual segments of the annular spacing are not completely filled out by the 4 bags containing SUP, which allows for some defomation when bending the conduit, without any significant outer forces being exerted on the bags.

Although the 4 RUBs constitute some resistance to heat transfer, they are less effective than are the 4 SUPs; therefore, RUBs have been positioned diagonally i relation to the outer square of the conduit, so that the thickness of INS has maxima where INS is in contact with RUB.

Fig. 7 shows a cross-sectional view of a conduit according to a fifth embodiment of the invention. Here, a super-insulator, SUP fills out the space between two metal pipes, PIPE2 and PIPE3. The outer PIPE1 could also be made of metal, or of a polymer. The insulator, INS, inside PIPE1 could be made of some polymer which combines flexibility with sufficient mechanical stability, so that the 3 inward protrusions of INS to establish contact with PIPE2 provide sufficient support for PIPE2 where the conduit is bent, i.e. its axis perpendicular to the cross-section showed follows a curved line. A third requirement for INS that it provides thermal insulation for fluid contained in the 3 partly annular sectors; as indicated by designation CHA, R, it is envisioned that these 3 sectors all convey return channel part flows. In the center, inside PIPE 3, we have the forward flow, CHA, F. That is, return flow essentially circumvents return flow. If the fluid flowing in CHA, R is of low temperature, the heat loss to the surroundings by this arrangement can be kept low even with moderate heat insulating capacity of INS.

The super-insulator, SUP should be of sufficient compression strength to hold the inner pipe in such a position, that the thickness of INS nowhere becomes too small in cross-sections of a bend of the conduit. At the same time SUP should behave flexibly in bending of the conduit. This poses some demands on the character of SUP which can be fulfilled by a suitable microstructure of SUP, permitting relatively smooth repositioning

of the individual grains of fiber of SUP when exerted to mechanical forces from the outside.

Figs. 8a and b show a sixth embodiment of the invention where vacuum inside super-insulators, SUP,F and SUP, R, surround a forward flow channel CHA, F, and a return flow channel, CHA, R, respectively. A vacuum suction channel, CHA, EVA is arranged adjacent to both flow channels, communicating with the super-insulating insulators by perforations, PERF. All three channels are embedded in an outer, flexible insulator, INS. The perforations should be sufficiently small to prevent any grains from the super-insulator to be sucked into the evacuation channel; alternatively, either the outer envelopes of the super-insulators or the perforations as such may be provided with a textile web with minute perforations, smaller than the size of any grains, but large enough that no excessive pressure drop occurs over the textile.

For simplification, in fig. 8b, for the sake of simplification of the figure, only connection to a single building, BUILD, has been shown. An evacuation pump, EVAP, maintains vacuum by connection to the evacuation channel, EVS. Each conduit, CON, has its evacuation channel closed off at or inside the building by a SEAL.

From fig. 8b it can be seen that it has been assumed that the building, BUILD, has been fitted with a storage type hot-water heater. In comparison with instantaneous water heaters this reduces demands on sizing of PIPE, F and PIPE, R. These pipes can be designed to combine strength with inner smoothness, to be maintained even after years of service, i.e. resisting corrosion and erosion, by making them of a metal, e.g. copper, and applying thin polymeric layer to the inner surface. This will permit rather high flow velocities,

say up to around 2 m/sec, and pressure up to, say 10 bars. Thereby small flow section diameters can be attained. Thus, fig. 8a could be taken to show a cross-section in full size. If the conduit is arranged vertically (as it is shown in the figure), it will only be necessary to dig a very narrow ditch in the ground, to embed the conduit.

In particular when pipes carrying relatively small amount of time-average heat flow are concerned, as is the case in particular with service pipes leading up to single-family dwellings, there is a geometry-related benefit from lowering the heat conductivity ? of insulation materials, which goes beyond the direct effect of lowering the heat conductivity as such: This extra effect, which is well-known in heat-transfer theory, for the sake of simplicity can be discussed with reference to a conduit of circular-symmetrical configuration, comprising a single fluid flow channel:

Supposing that in a calculation the inner diameter is kept constant, and the outer diameter of the insulation is being gradually increased, the marginal benefit in terms of added heat insulation per unit of diameter increase gradually diminishes. In the case of an insulated pipe, which is not buried, but is surrounded by air, heat is given off from the surface by convection. In that case there will even be a certain outer diameter which minimises the heat loss, that is, further outer diameter increase will even increase heat losses. Another example of the geometry effect: If, for a given outer diameter the inner diameter is being diminished, the benefit from this depends upon the heat conductivity. Thus, when conventional heat insulating materials demand a relatively big ratio of outer-to-inner pipe diameter, as is the case with service pipes of single-

family dwellings, there is a strong incentive to look for more efficient heat insulating materials.

This consideration underlines the interest of the various types of conduits employing super-insulators. When integrated into the invention, such conduits become even more attractive, since they help keep the envelope size of co-extending conduits, and thus casings, CASa, of moderate dimensions.

Below a set of criteria quantifying new, more efficiently insulated conduits is given, taking as a reference state-of-the-art conduits employing insulating foam with a heat conductivity in the order of 0.03 W /mK:

Criterion A: New conduits comprising heat insulating material(s) with heat conductivity being less than 0.03, less than 0.015, less than 0.007, less than 0.003, or even less than 0.001 W / mK.

Criterion B: New conduits for which an average heat conductivity is defined as the conductivity of a theoretical conduit of uniform conductivity, completely filling out the space between inner and outer envelopes of the conduit in question, that is including parts of the conduits which are not made of material with exceptionally low heat conductivity, this average heat conductivity being equal to 0.03, less than 0.03, less than 0.015, less than 0.007, less than 0.003, pr even less than 0.001 W /mK.

Criterion C: New conduits having the same, or only moderately higher, or lower heat loss per unit length of conduit than that of a comparable state-of-the art conduit operation at the same fluid temperature(s), transporting the same amount of heat rate, the new conduits having outer envelope size being less than 0.7, 0.5, 0.3, or even 0.1 times the size of the outer envelope of the state-of-the-art conduit.

Fig. 9 shows a schematic of a seventh embodiment of the invention, in which a less common, but per se previously known, 2-line system (displayed simplified with only one building etc., as in fig. 3), where cold (drinking) town's water, CW is arranged to be fed into the distribution system centrally, i.e. into the branching station, STA, to be heated for supply of hot service water, HW, to the buildings: The same fluid is also used for space heating services, giving off heat, via a heat exchanger, HERAD to a hydronic heating system with internal radiators, RAD, since oxygen is dissolved in the water. Big district heating systems with centrally produced hot service water have been built in a number of Russian cities. Smaller systems, according to fig. 9, and using polymer conduits, in Sweden are known as 'Grudis' systems, which have been built in some few cases, but have not yet been adopted in any great number. The present invention could provide a new start for such systems, which offer appealing possibilities of first cost savings.

An advantage with a scheme essentially relying on distribution of hot service water, as in fig. 9, e.g. when compared with the closed loop system of fig. 3, is that in fig. 9 conduits may be designed without barriers to oxygen diffusion, such a metal folio. Thus, the scheme of fig. 9 lends itself to an all-polymeric conduit design. A concern may be that polymeric channels for hot water could promote microbial growth (e.g. the Legionella bacterium), especially in the return line, where temperatures will typically be lower than 50°C; one way of handling this problem could be to add anti-microbial copper to the polymer surface.

In fig. 9, an Electrically driven heat pump, HP, drawing HEAT from an external environment, such as for instance outside air or ground water, is shown as an

example of a centralised source of thermal energy comprised within the branching station, STA.

Fig. 10 shows (like-wise simplified, to show only one building etc.) an eighth embodiment of the invention, incorporating a 4-line distribution system (claim 21), composed of a 2-line closed loop forward, F, and return, R, line system for building heating or cooling, depending on the season (claim 22), and a 2-line loop for loading a tank, Ta, inside each of the buildings, with hot water to be supplied via a forward line, HWF, when cold water is taken out from the bottom of the tank and fed into return line, RW, for centralised heating of cold water, CW, into hot water, HW, in the branching station, STA.

Heat and / or cold is supplied to the branching station, STA, from a 4-line district heating (HEAT) and district cooling (COLD) system, DISTR*. Whenever hot service water is needed, this is served via heat exchanger HE1, which typically will be in operation for some intervals during the day, or maybe more or less continuously, most or all the days of the year. In the cooler part of the season, forward line, F, serves distribution of district heating water, which is heated in heat exchanger HE2, and in a warmer part of the season the same line serves distribution of district cooling water which is cooled in heat exchanger HE3. That is, the 2-line system composed of F and R operates as a switch-over system. Settings of 3-way valves, 3VA', 3VA´´, and 3VA´´´ in the forward and return lines inside the branching station and in the building, respectively, will determine which of the two alternative modes is in operation. The 3-way valves in the branching station are shown to be shifted automatically by signals from the signal handling unit, SIG, according to recorded level of the ambient temperature, TA. In-

side the buildings, radiators, RAD, are in operation in the cooler part of the season, and fan coils, FC, are in operation in the warmer part of the season, as determined by controller C'.

A simpler variation of the system shown in fig. 10 does not include cooling services, whereby a number of components, including 3-way valves, become superfluous. Today in most countries with a large district heating sector, air conditioning of single-family houses is not very common. But it can be envisaged that in future a possibility to cool private homes, including single-family houses, will be seen as attractive. Building simplified systems according to fig. 10, provides the possibility of changing individual F / R loops to include the district cooling facility when cooling of the corresponding building becomes a reality. In the simplified scheme of 4 lines, circulation of the F / R loop can be shut off in the summer season. When the HWF and RW channels are designed with small diameters, the heat loss from such a system will be lower in the summer season, compared to a similar 2-line system, where circulation is maintained all year round in bigger F / R channels.

Inside the tank, Ta, hotter and less dense water is stored on top of colder water by thermal stratification in a per se known manner. Cold water, CW, is supplied to the tank from a drinking water system to the tank at its bottom, when hot service water, HW, is drawn off by opening of one or more hot water faucets, FAC, inside the building. As soon as the tank looses some of its stored amount of hot water, a temperature sensor at the bottom of the tank registers this, whereby re-loading of the tank by opening of valve, VA, is activated.

A tank storage system of the kind shown in fig. 10 is known from district heating and from other methods of serving buildings with heat energy, e.g. local heat pumps serving individual buildings, except for the fact that in fig. 10 hot service water is heated centrally, i.e. not inside the building but at a distance from the building, and in a heat exchanger, which will typically be common to a group of buildings where tanks are installed. In comparison with simpler connection schemes, such as for instance the one shown in fig. 9, the sixth embodiment of the invention, incorporating a 4-line system has some attractive features, as will be explained here below. These attractions would in principle apply also to any thermal energy distribution system built according to the scheme of fig. 10, i.e. including a conventional network necessitating use of many T-branchings of channels and conduits.

In a conventional district heating system according to fig. 10, one might arrange all 4 channels inside the same conduit (as in fig. 5b), or one could for instance use 2 conduits running parallel, with 2 channels inside each conduits. In both these arrangements, it would certainly be possible to accommodate T-branchings, but quite an amount of on-site work would be required, and the 3-dimensional geometry of these branchings will place various demands on exactly where to place the 4 channels inside the cross-sections of conduits. When instead a 4-line scheme, as the one shown in fig. 10, is arranged by using an energy distribution system according to invention, where no branchings are made directly on conduits, no such restrictions exist.

In fact, it may be claimed that the more lines and channels are used in a particular district heating / cooling scheme, the more the advantage of dispensing

with T-branchings will come into its right. For example, in distribution systems according to the invention, it will represent no great complication to accommodate as much as 6 channels within a single conduit. In cases where heating of some buildings is required alongside with cooling of other buildings, it can be natural to design distribution systems with 6 channels: 2 channels for central production and distribution of hot service water, 2 more channels for district heating, and finally 2 more channels for district cooling. A switch-over system (claim 22), where 2 channels in the winter season are used for district heating and in the summer season for cooling of course in one sense is a simpler solution, but this solution requires that the group of buildings served perform rather equally in terms of when heating and cooling is needed, a requirement which may not always be fulfilled. As one example, in a temperature climate, like the Scandinavian, older single family houses with little thermal insulation may call for rather little cooling in summer, where it may attractive for the inhabitants to spend some time of the day in the garden, if they are at home at all in daytime hours. By contrast, modern office buildings, with substantial thermal insulation, and other features to keep down heating demand on cold days, with big windows and with a lot of heat generating PC-s and other equipment, as well as people generating heat, often call for of air conditioning i.e. cooling, not heating, in a major part of the year, i.e. not only in the summer.

Now, returning to explaining the advantages with a connection scheme as shown in fig. 10:

First: If hot service water has to be produced instantaneously in heat exchangers, not in prolonged time intervals, due to evening-out effect of a tank, the re-

sulting peak loads on the distribution system are felt particularly hard in the case of single family houses, because of a big relative load variation. - In large buildings there is an automatic evening-out effect due to diversification in time of tappings in individual apartments. Thus, with single-family houses, tanks can be used for selecting smaller diameters of channels in service pipes leading up to buildings. In the system shown in fig. 10, very small diameter pipes can be adopted for the lines HWF and RW, which can contribute to decrease heat losses and / or to reduce conduit sizes.

Second: When a group of single-family houses is served by the same branching station, STA, they will in fact often perform rather equally in terms of thermal load variation with outside air temperature, so that conditions may be rather favourable for adopting a switch-over solution. Often groups of single-family houses have been built within the same year, or within the same decade. In the first case, they may even have been made by the same firm. Still, even if groups of buildings behave almost identically, conditions may not be ideal for using the switch-over scheme: The temperature differential between the forward and the return line will tend to be substantially bigger in the district heating mode than in the cooling mode, which could present a mis-matching problem of channels for cooling needing to be bigger than channels for heating. How well channel sizes needed for heating and cooling match has to be considered specifically in a given case, to decide if a switch-over solution is appropirate.

Third: According to fig. 10, hot service water, HW, is prepared from cold water, CW, which is (via WR) led to the branching station, STA (claim 15), and heat-

ing is catered for by distribution lines separate from lines serving hot water preparation. These conditions are favourable to the use of Friction-Reducing Additives (FRAs), such as tensides, which in the last few years have been developed, tested and applied (not least in Japan) with success. Such additives can be tailored (by modifying their chemical composition) to perform optimally at in various temperature intervals. Also, newer types of FRAs have been shown to be bio-degradable in soil. Still, so far, in some countries, like the Scandinavian countries, FRAs have mainly been considered for use in big district heating transmission systems, separated from local heat distribution networks by heat exchangers. For most existing district heating systems the use of FRAs is considered problematic, since one always has to consider the risk of district heating water by accident leaking into drinking water systems. Although the tensides in question are not considered particularly poisonous (as for instance the de-oxidising substance hydrazine, sometimes being added to district heating water), the mere possibility of a 'foreign' chemical substance leaking into a drinking water system by authorities in most countries is not accepted. It is a fact that when hot service water is prepared separately in each building, experience shows that district heating water occasionally does leak into drinking water systems. This could happen in an event of a leaking heat transfer coil of a storage heater, combined with a higher pressure on the district heating side than on the drinking water side, combined with the mishap of mal-functioning non-return valve in the drinking water supply line.

But with a system according to fig. 10, it can be argued that the risk of leakage into the (CW) drinking water network can be reduced so much that use of ten-

sides could be regarded as acceptable. For instance, heat exchanger HE2 can be made with double walls, to make a mixing media virtually impossible. Using FRAs in local distribution systems, like the one shown in fig. 10 can be utilised for selecting small diameters of channels for space heating / cooling (F and R).

Fourth: Provided the tank is of sufficient size, it can to a great extent even out the load on the distribution systems, caused by tappings of hot water, which will vary substantially with time, especially in the case of single-family houses. Thus, for example, if a conduit cross-section of the type shown in figs. 5a and b is modified for application in a 4-line system as described, one can select small diameters of channels for hot water provision (HWF and WR).

Fifth: When service water is heated centrally to be fed into a tank, it becomes attractive to fit the signal handling equipment, SIG, with intelligent procedures to optimise loading of individual tanks, That is, in addition to the local (i.e. of the building) control, represented by thermostatic valve, VA, branching line channels of the branching station, STA, may be fitted with valves, VA1', to be controlled by SIG, for instance to adjust the loading flowrate (measured by a flow meter, FM1'') according to the individual consumption pattern of the building and / or to spread out in time starts of loading of tanks belonging to individual buildings. Alternatively, the loading pump, PU1, may be controllable from SIG. This will cause evening out / diversification of the heat load posed by distribution system, DISTR, on the district heating, HEAT, part of distribution system, DISTR*, from which heat is supplied to the branching station, STA. This kind of centralised control should of course not be driven to such extremes that people living in the buildings will

experience shortage of hot water. SIG may even be programmed to adapt loading of individual tanks to individual consumption patterns, so that a faster loading takes place in a building with an above average hot water consumption.

Sixth: When space heating (+ possible cooling) and hot service water provision is served by 4 lines instead of 2 lines, separate metering of 2 energy rates (or mass flow rates) are called for, which provides an opportunity for the energy company to supply the customers with information about how the total energy consumption is divided between space heating and hot service water; such added information can be of value to the customer, e.g. if he wants to asses effects of measures taken to reduce energy consumption. The downside is that more metering is associated with this extra information service. Here, the invention comes in handy, because of the rationalisation of metering which becomes possible, due to concentration to the branching station as previously explained.

Fig. 11, which is a drawing of a branching element of any embodiment of the invention, illustrates how such a concentration of metering can materialise. The total branching station, STA, is understood to comprise an appropriate number of branching elements, all connected to the same signal handling unit, SIG (a number of arrows pointing towards SIG in fig. 11 indicate signals to and from various elements not shown, including elements the branching element(s) not shown). The branching element, BRA2, shown in fig. 11, can be almost identical for lines R and WR (cf. fig. 10), while branching elements serving lines F and HWF can be modified versions of BRA2, for instance to comprise no flow meters, but instead each to comprise a common thermal sensor (upstream of branching) and valves fitted into

each branched line. In fact, branching elements used in any of the previously shown embodiments of the invention can be designed as variations of BRA2 shown in fig. 11.

The entire branching element, BRA2, is shown to include thermal insulation, INS, of all parts. 3 return line channels, RCHA1, RCHA2, and RCHA3 are shown in the figure, and more such lines can be imagined. Each channel includes a classical venturi type piping element, V1, V2, V3 ..., in which the flow is narrowed down to a smaller pipe diameter from which the diameter in a diffuser part gradually expands back to the original diameter at flow outlet into a BOX, where mixing takes place, and from which a bigger pipe, CHA, leads the aggregate fluid flow further from the box, for heating in one the heat exchangers (not shown in fig. 11) of the branching station, STA. Flow meter FM2 can be of a type commonly used in district heating practice, such as e.g. an ultra-sonic flow meter. A flow straightener, STR2, is arranged upstream of the meter, to even out skewness and / or rotation set up in the flow profile at inlet to pipe CHA. Each venturi element is fitted with two pressure sensors to record the pressure differential, ?p1'', ?p2'', ?p3'', set up in the converging part of the venturi, the size of this pressure differential being a measure of the flowrate, i.e. the venturies fitted with pressure differential sensing are in fact flow meters, FM1'', FM2'', FM3'' ..

The pressure sensing elements can be of the piezo-electric type. As can be seen, each of the branched lines also includes a temperature sensor, TS1'', TS2'', TS3'', which can be of the resistance type or of the thermo-couple type. As the big flow meter, FM2, all the small venture type flow meters are supplied with a flow straightener, STR''1, STR''2, STR''3, ... upstream of

the meter, to reduce the effects on metering of flow profile skewness, which will be caused by bends and other deviations from a straight pipes upstream of the meters.

A number of advantages of concentrating metering equipment in the branching station have been discussed already, such as simplification of procedures for taking out meters for calibration as assembly from the branching station, instead of taking out meters from each building. By discussion of fig. 11, several further, appealing and distinctive features made possible by the invention can be pointed out:

(1): The branching element, including metering / sensing equipment is compact,

(2): By adopting an appropriate calibration procedure, flows and temperatures can measured relatively independent of installation effects.

(3): The type of flow and temperature sensing equipment selected can be relatively cheap.

Ad (1): The compactness is attributable to 2 features: Use of flow straighteners to eliminate long, straight pipes, and to the use of small sensors for pressure and temperature on individual channels.

It is true that a flow straightener arranged rather close to a flow meter, as indicated in fig. 11, will influence the calibration curve (reading of electrical signal vs. flow rate) of the meter, but this effect can be eliminated by calibrating the meter together with the flow straightener. In fact, meters and sensors of the branching element should be calibrated as they are arranged in the branching element.

Ad (2): Due straighteners STR''1, STR''2, STR''3, ... effects on measurement of skewed flow profiles caused by bends etc. upstream of the branching element are reduced. However, since straighteners do not func-

tion perfectly, if bends are arranged close to the branching element, measurement accuracy can be improved by including such bends in the branching element, i.e. calibrating with such bends not being dismantled prior to calibration.

Ad (3): The cheapness to some extent is related to the fact that point measurements are made instead of bulk flow measurement. Thermal sensors applied to a point, as indicated in fig. 11, can make temperature recording sensible to any thermal stratification of flow remaining downstream of the flow straightener. To a great extent, without increasing the dimensions of the branching element, this can be compensated for by designing the resistive sensor as a ring to extend all, or almost 360 degrees round the periphery of the pipe.

One of the requirements on flow meters for installation in district heating substations that generally tends to call for expensive equipments is that the meter should measure accurately within a great span of flow rates, e.g. 1:100, a requirement which is particularly demanding in the case of single family houses equipped with instantaneous hot water heaters. In the scheme of fig. 10, due to the presence of tanks, there is no great variation of flow rates. This corresponds well with the selection of venturi flow meters, since they rely on pressure differential coupled to differences in dynamic pressure, i.e. a quadratic type of relation to flow rate. With such a relationship, signals become very weak at low flow rates.

Other types of compact, low-price flow sensors than piezo-electric pressure differential sensors are available in the market, such as e.g. thermal flow sensors, which may be better suited in branching stations of system configurations where hot water tappings are

directly reflected in flow rate variations, to be measured in the branching station.

Fig. 12 shows a ninth embodiment of the invention in which forward, F, and return, R, conduits, CON, defined as the inner pipes (not insulation and casings), serving the same building (not shown) run in different cavities, CAVa´and CAVa´´ inside casing CASa, along their CONa parts and merge into a common casing CASc of their CASc parts. The CONc parts may be bonded to insulation INSc, or there may be a small spacing in-between, so that conduit parts CONc can slide axially inside insulation INSc. Conduits, as they are definied according to this wording, do not themselves comprise any significant insulation. An alternative description would be to interpret the whole assembly: 2 times CONc, INSc , and CASc as a conduit whose central parts split up in the direction backwards to the branching station (not shown in fig. 12). If CONb parts are short, it may be permissible to leave out insulation around these conduit parts. Fig. 12 shows instead an embodiment where additional insulation, INSb, has been arranged around curved parts CONb, inside a casing, CASb.

Fig. 13a, b and 14 show a tenth embodiment of the invention where forward, F, and return, R, lines, serving the same building (not shown) are completely separated. Also, this embodiment shows how a system according to the invention can based on very simple conduits, keeping sizes of casings, CAS' and CAS'', rather small, those casings containing forward, F, and return, R, channel conduit parts CONa' and CONa'', respectively, inside cavities CAVa' and CAVa'', respectively.

Fig. 13a is a cross-sectional side view, and fig. 14 is a sectional view from above.

Fig. 13b shows an enlargement of one (forward-line) conduit CONa'. It can be seen that the conduit

comprises an inner metal (e.g. copper) pipe, MET, and an outer, polymeric (e.g. high-density polyethylene) coating layer. This coating layer breaks any galvanic currents that might otherwise be set up outside the conduit and provides mechanical protection of MET. In addition, POL provides some 'residual' heat transfer resistance, i.e. a thermal resistance that on the one hand is not sufficient for generally providing insulation of conduits, but on the other hand, since polymers generally exhibit lower thermal conductivity than do metals, provides much better resistance to heat losses than do naked metal pipes; this can be of advantage with locally lowered heat insulation along conduits, e.g. at conduit parts CONb (curved parts leaving the assembly of co-extending conduits).

In fact all conduits parts are provided with added heat insulation: INSa' to CONa'. INSa'' to CONa'', INSb' to CONb', INSb'' to CONb'', INSc' to CONc', and INSc'' to CONc''. Insulations CONb' and CONb'' are provided by re-fill soil, SOILins, having a lower heat conductivity than has other SOIL surrounding the embedded system.

It can be seen that the system has been system designed that water can in fact percolate into cavities CAVa' and CAV'' as weel as into annular clearings between insulations INSc' and INSc'' and conduit parts CONc' and CONc'', respectively. This can be acceptable under the premise that such water does not compromise the thermal integrity of any system parts being exposed to water. Insulations can be made such that they will not become soaked with water. After all, water which stands still does not conduct heat very efficiently. Some designs according to fig. 13 may be restricted in use to locations where they will be well above the water table in the ground.

It is true that the only moderately insulated conduits CON provide possibilities for heat flows between individual conduit parts CONa' and CONa'' inside cavities CAVa' and CAVa'', respectively. However, in the forward line case, fluid flows will be of almost the same temperature. Return flows will in general not be of the same temperatures, i.e. heat flows will be set up between individual conduit parts CONa''. In general this will not be any problem, since return flow will be mixed anyhow, once they reach the return flow branching element (BRA2 in fig. 11).

In special cases, one may single out a group of buildings with especially low return temperatures to be utilised for a good thermodynamic performance of a heat pump connected to these special return pipes. In that case, heat transfer between individual return conduit parts CONa'' may be unwanted and should be taken care of.

Figs. 15 - 17a-c show an eleventh embodiment of the invention. Fig. 15 is a longitudinal, sectional view; fig. 16 is a view from above, earth on top of the embodiment having been removed; figs. 17a-c are three cross-sectional views, as indicated in the two preceding figures.

In this embodiment, in total 7 conduits, CON, are arranged inside a casing, CASa, departing from the casing by penetrating the top of the casing by elastic deformation of the casing. As fig. 17c shows, the casing all along its longitudinal extension comprises a separation plane, SEP. In a preferred design of the invention the casing is such fabricated that the two meeting surfaces, SURF, at SEP are pressed together and/or a covering TAPE is fastened to cover the separation, so that it is water-tight from the outset. All surfaces of the casing, comprising: the outer surface in contact

with soil, the inner surface circumscribing the cavity, CAVa, and the assembly of conduits, as well as the two surfaces, SURF, in contact with each other at SEP, all the way round are compact, rugged and substantially impermeable to water. The casing together with its interior, insulating part, INSa, is deformable, preferably completely or at least partly elastically deformable, so that when separating, horizontal forces, FO (cf. fig. 17b) are applied to a cross-section at any location along the casing, and TAPE has been removed along an appropriate length of the casing, the casing will tend to reverse to its initial, closed shape or, when a body is inserted, will exert forces upon this body.

As can be seen from the figures, this design of the casing has been utilised for permitting conduits to penetrate it, the figures showing by example the first conduit leaving the casing by deformation of the conduit in two planes along its part CONb: First the conduit bends mainly upwardly, combined with a slight bending towards the middle of the cross-section, to penetrate the casing through SEP. Then, having passed all the way through the casing, the conduit bends 90 degrees in the horizontal plane, to leave the casing in a direction substantially perpendicular to the casing by conduit part CONc, which is continued up to a building, BUILD (not shown).

Openings are thus created by deformation of the casing, not by taking away material from the casing by cutting, grinding etc. This speeds up installation, in particular when conduits are to be inserted at a later stage of network development. Openings are created in situ, where needed, either by simply drawing or pressing the conduit through the casing, or with the assistance of one or more appropriate tools.

By appropriate design of casing and conduit cross-sectional shapes and surface finishes, it becomes possible to create a structure by which the casing by itself closes completely around the penetrating conduit, so that at all cross-sections, including all those not shown in figs. 16a-c, either two surfaces of the casing itself are pressed together, or there are contact zones between a surface, SURF, of the casing and a surface of the conduit.

Still, ageing of material, settings in the ground, etc. after shorter or longer time of operation of the system could create openings around a penetrating conduit. In order that water-tightness, if needed, be maintained, one might apply GLUE (cf. fig. 16a and b) around the conduit, wherever TAPE has been locally removed. Another alternative could be to design the system such that water-tightness at conduit penetrations is not a pre-requisite, as discussed here above in relation to fig. 14. A classical district heating culvert principle, which has been used in old designs where conduits were placed inside concrete culverts and could be applied here as well, is to arrange the culvert / casing CASa with a slight longitudinal slope towards a location where drainage is provided for. In any case, insulations, INSa and INS of casing and conduits, respectively, preferably are made such that they will not soaked if exposed to water. This can be achieved by using closed-cell foam as thermal insulation.

As can be seen from fig. 15, conduit parts CONc can be arranged rather close to the ground surface GS. This, in combination with a conduit profile of small horizontal extension, allows for rather little earth (trench, TR) to be removed if conduits up to buildings are arranged underground by digging, carving etc in the ground.

An alternative to the arrangement shown could be to turn the cross-section 90 or 180 degrees, so that conduits leave the casing from a side of the casing or downwards.

CLAIMS

1. A thermal energy distribution system for supplying several buildings with thermal service, **characterized by**

a branching station,

several conduits each forming an essentially unbroken connection from said branching station to a thermal connection in each building, each conduit being flexible and having essentially the same cross-section over the entire length thereof, and

at least two of said conduits extending essentially adjacent to each other over a first portion, and extending to each building over a third portion and having a second portion forming a transition between said first and third portion.

2. The system of claim 1, **characterized in** that said first portion of said adjacent conduits being arranged within a casing.

3. The system of claim 2, **characterized in** that said casing or said conduits being provided with thermal insulation.

4. The system of any one of the preceding claims, **characterized in** that each conduit comprises a first line comprising forward flow and a second line comprising return flow.

5. The system according to any one of claims 2, 3 or 4, **characterized in** that said casing is provided with a longitudinal slit, which is normally closed, and is openable at selectible positions along said casing for forming an opening through which the second portion of said conduit may pass.

6. The system of any one of the preceding claims, **characterized in** that said conduits are prefabricated in the form of an integrated polymeric structure being

fabricated from the same base material and in a simultaneous manufacturing operation.

7. The system of any one of the preceding claims, **characterized in** that the outer shape of said conduits is square, rectangular or hexagonal, whereby voids between the first portions of the conduits are minimized.

8. The system of any one of claims 4-7, **characterized in** that the flow in the forward line is essentially the same amount of flow being returned in the return line.

9. The system of any one of the preceding claim,s **characterized in** that each conduit comprises at least three lines, a forward line for heat energy, a return line for heat energy and a third line for hot water.

10. The system of claim 9, **characterized in** that the conduit comprises four lines, a forward line for heat energy, a return line for heat energy, a third line for hot water and a fourth line for return hot water.

11. The system of any one of the preceding claims, **characterized in** that said branching station is provided with individual thermal measuring equipment such as flow meters, for each conduit.

12. The system of claim 11, **characterized in** that the branching station comprises measuring equipment for measuring the overall flow rate for several conduits.

13. The system of any one of the preceding claims, **characterized by** an output flow meter and a return flow meter for each conduit, whereby a leakage may be indicated at deviation between the flow meters.

14. The system of any one of claims 1-13, **characterized by** a closing valve arranged in each conduit.

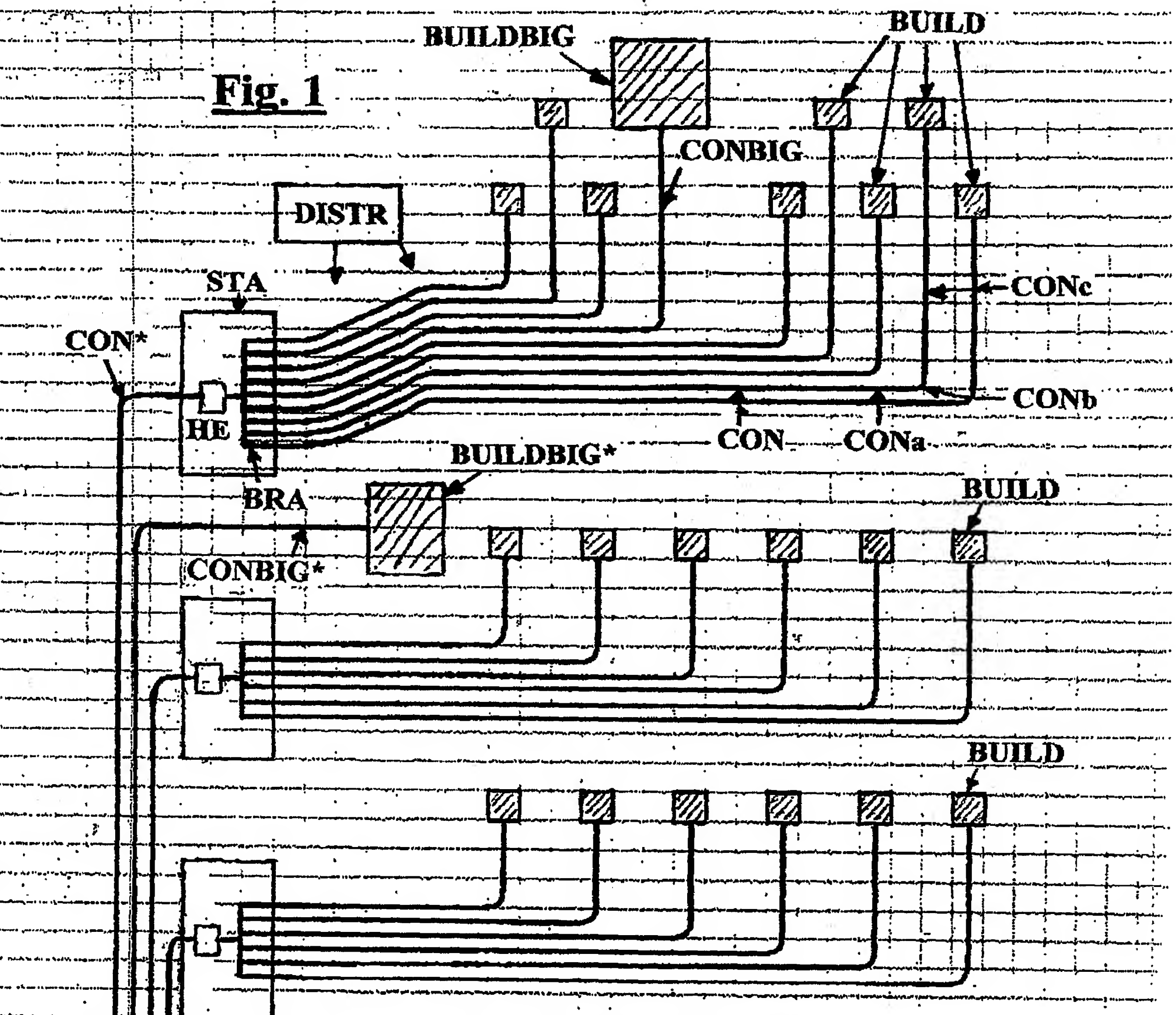
15. The system according to any one of the preceding claims, **characterized in** that said conduit said casing being provided with thermal isolation in the

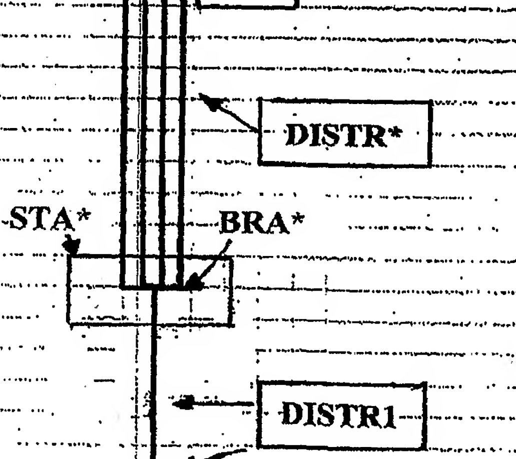
form of one or more super-insulating layers, each super-insulating layer comprising a space under essentially vacuum, said vacuum being maintained by a vacuum source arranged in said branching station and connected to said space.

16. System according to claim 15, **characterized in** that the space is surrounded by gas impermeable surfaces such as metal folios.

17. A system for providing hot tap water to a building, **characterized by** a branching station comprising a source for hot tap water, a feed line and a return line for feeding and returning hot water from the branching station to a building, a compensation tank provided in said building for forming an intermediate storage of hot tap water, and a hot tap water outlet therefrom, whereby the feed line and return line may be arranged with small diameter.

Fig. 1


BUILDBIG
BUILD
CONBIG
DISTR
STA
CONc
CON*
CONb
HE
CON
CONa
BUILDBIG*
BRA
BUILD
CONBIG*
BUILD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STA*
BRA*
DISTR1

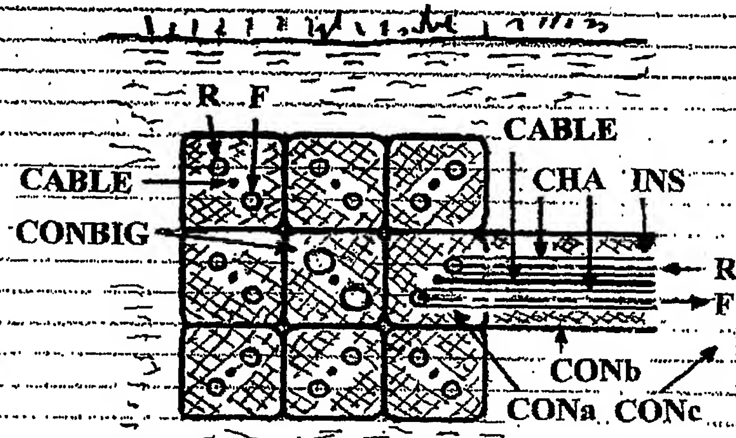
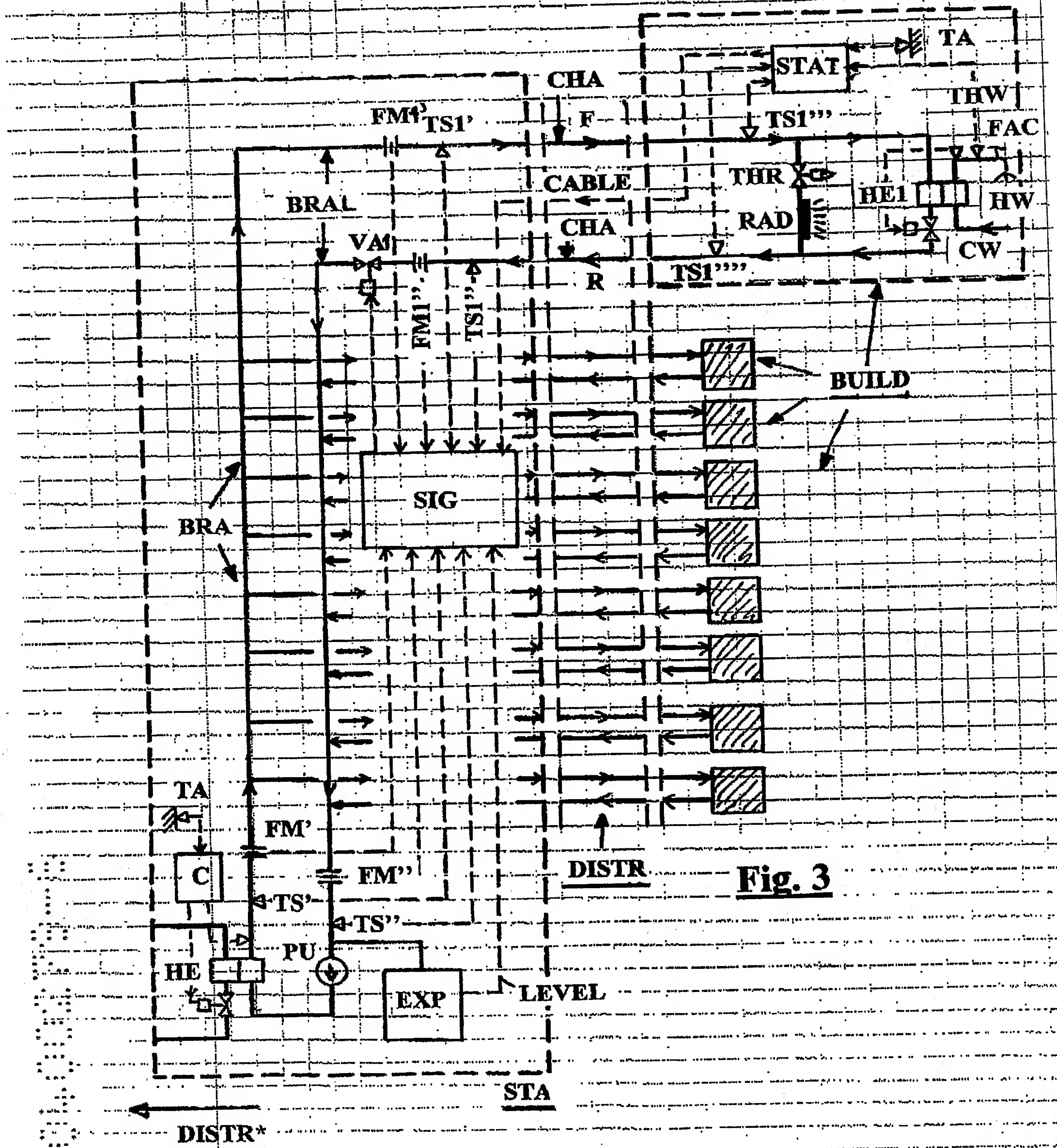

R
F
CABLE
CABLE
CHA
INS
CONBIG
R
F
CONb
CONa
CONc

Fig. 2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CHA
THW
FM1' TS1'
F
TS1'''
FAC
CABLE
THR
HE1
HW
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RAD
VA1
CHA
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R
TS1''''
FM1''
TS1''
BUILD
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TS'
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EXP
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DISTR
STA
DISTR*

Fig. 3

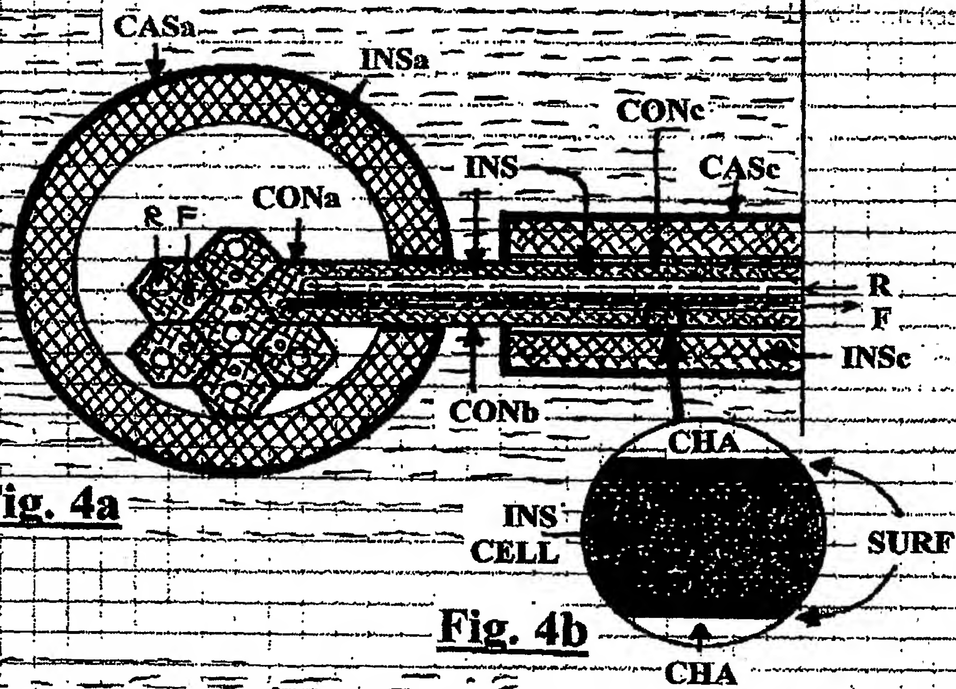


Fig. 4a

Fig. 4b

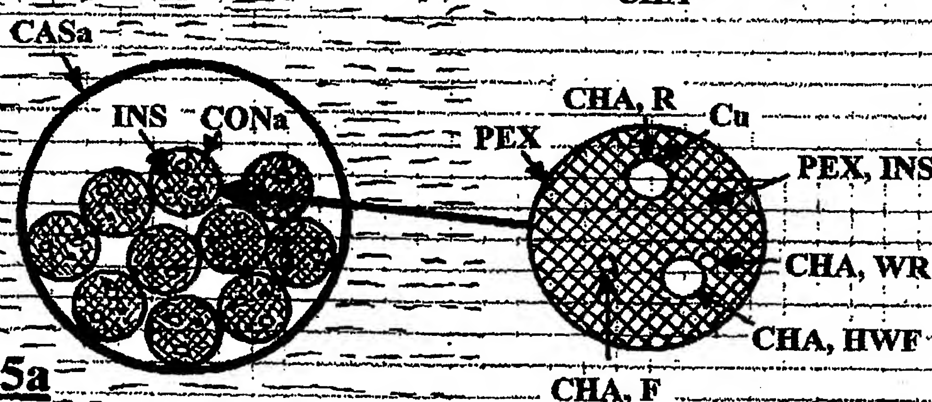


Fig. 5a

Fig. 5b

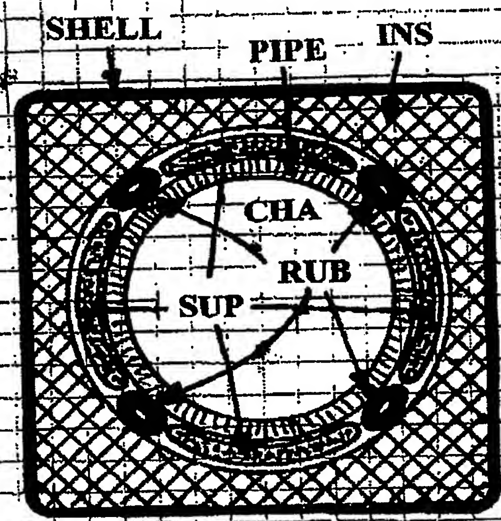


Fig. 6

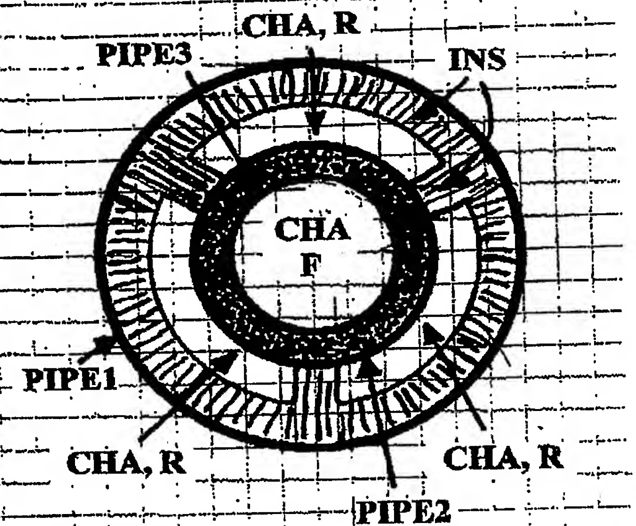


Fig. 7

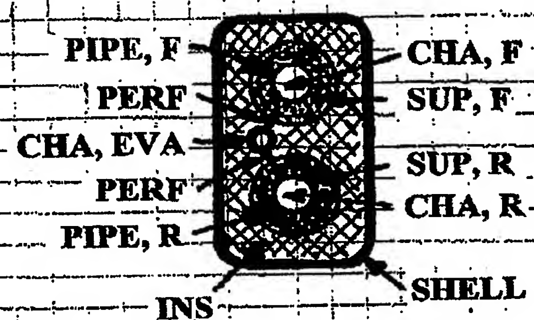


Fig. 8a

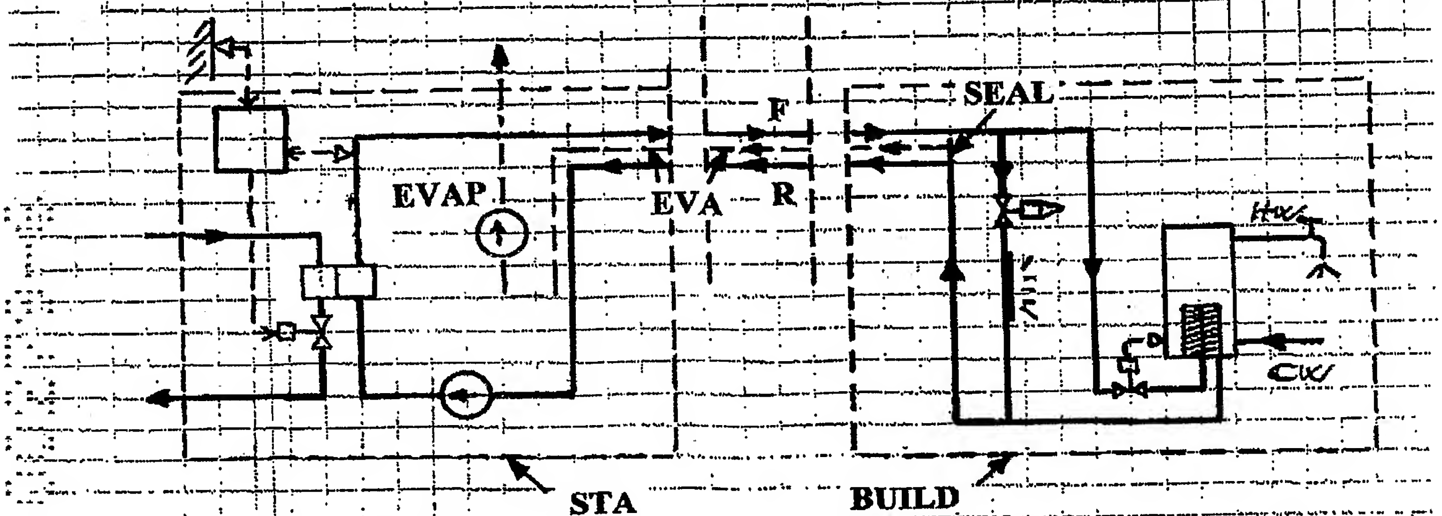
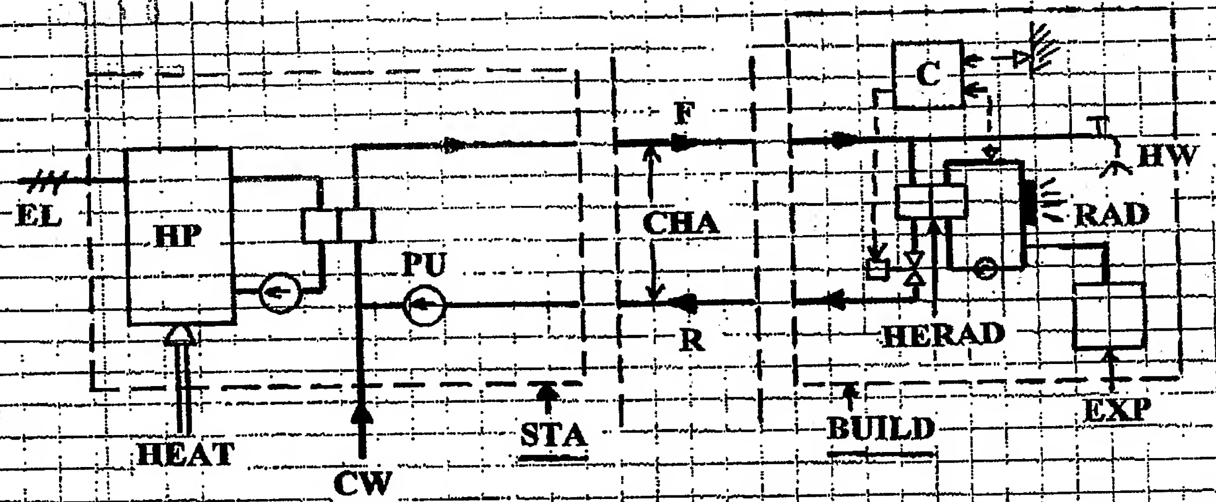


Fig. 8b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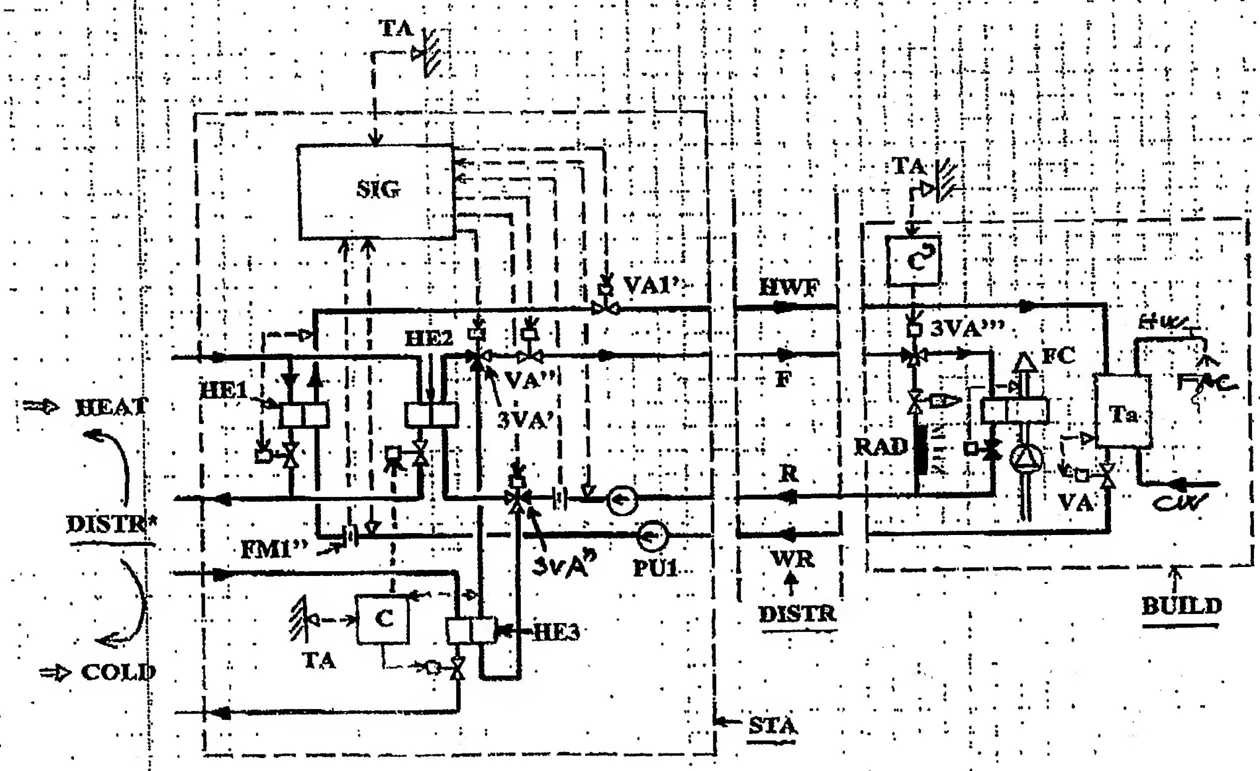
F
CHA
R
C
HW
RAD
HERAD
EXP
HEAT
CW
STA
BUILD

Fig. 9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HWF
HE2
HE1
HEAT
VA''
3VA'
DISTR*
FM1''
3VA''
PU1
C
HE3
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COLD
STA
F
R
WR
DISTR
TA
C
3VA'''
FC
RAD
Ta
VA
CW
BUILD

Fig. 10

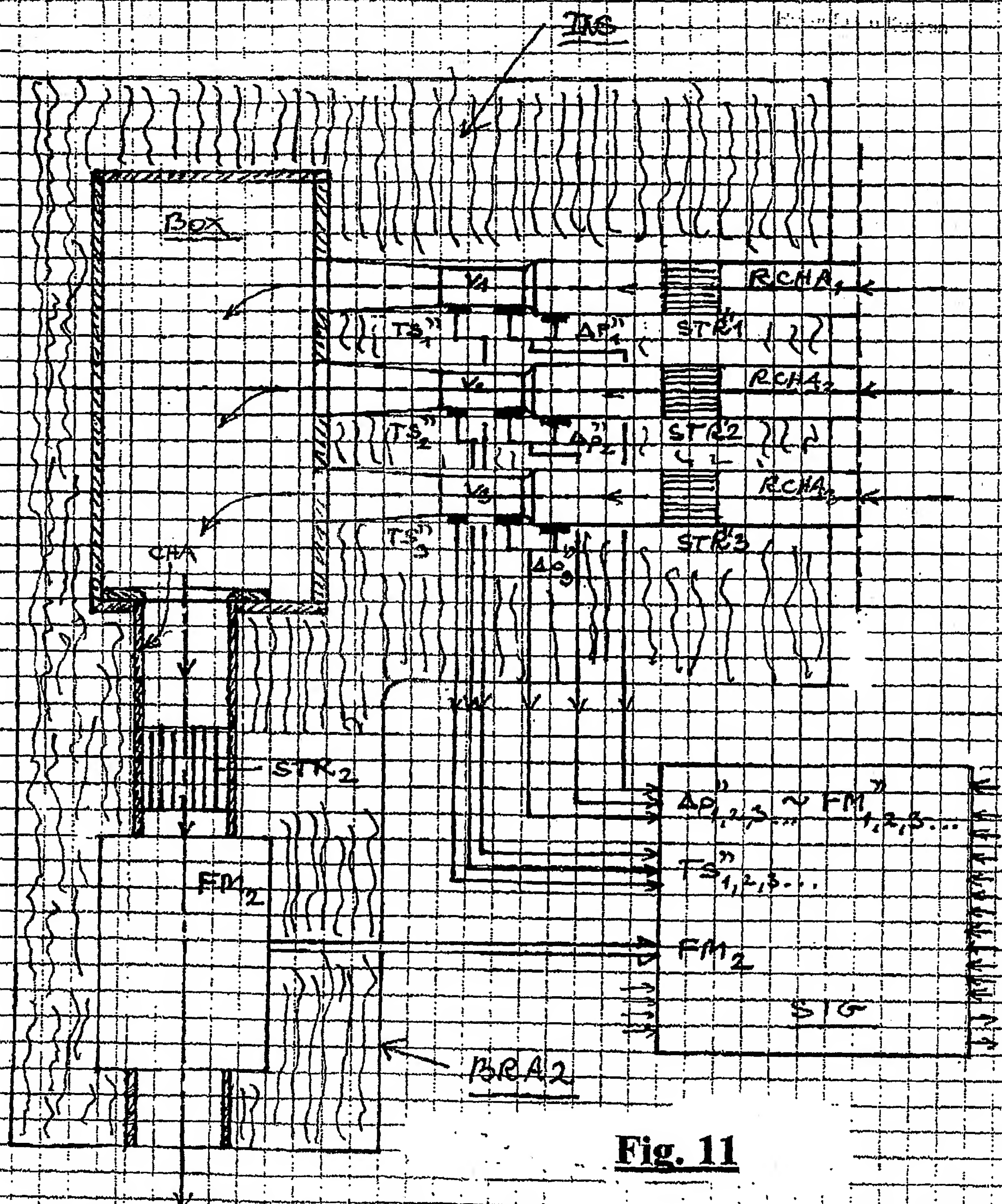

TVS
Box
V_1
RCHA$_1$
TS_1''
$\Delta P_1''$
STR'1
V_2
RCHA$_2$
TS_2''
$\Delta P_2''$
STR'2
V_3
RCHA$_3$
TS_3''
$\Delta P_3''$
STR'3
CHA
STR$_2$
FM$_2$
$\Delta P_{1,2,3\ldots}'' \sim FM_{1,2,3\ldots}''$
$TS_{1,2,3\ldots}''$
FM$_2$
SIG
BRA2

Fig. 11

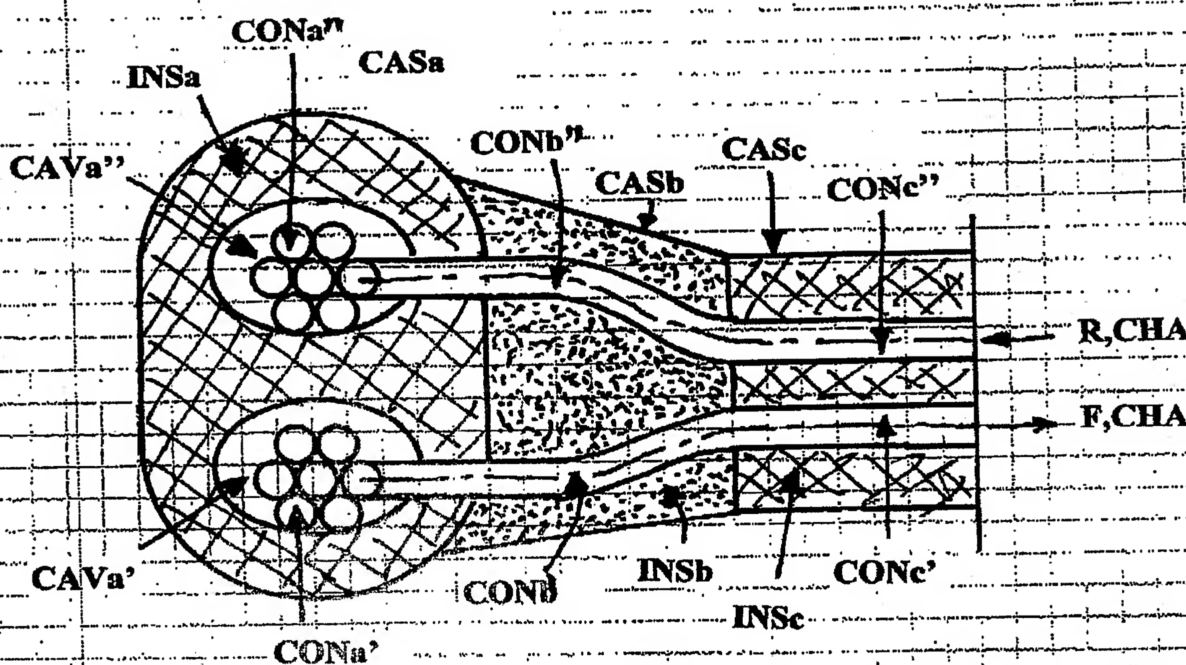

CONa''
CASa
INSa
CAVa''
CONb''
CASb
CASc
CONc''
R,CHA
F,CHA
CAVa'
CONb'
INSb
CONc'
INSc
CONa'

Fig. 12

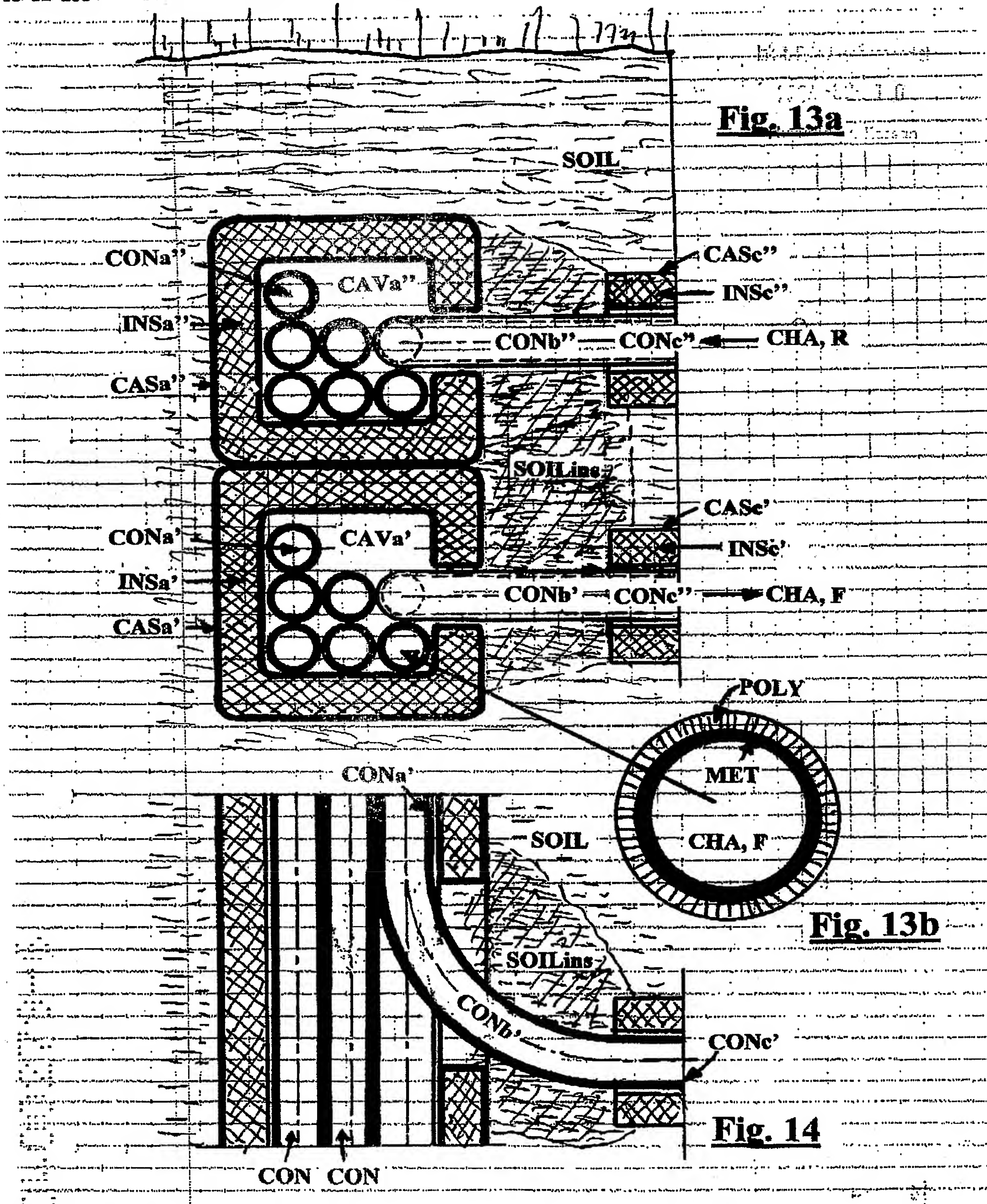
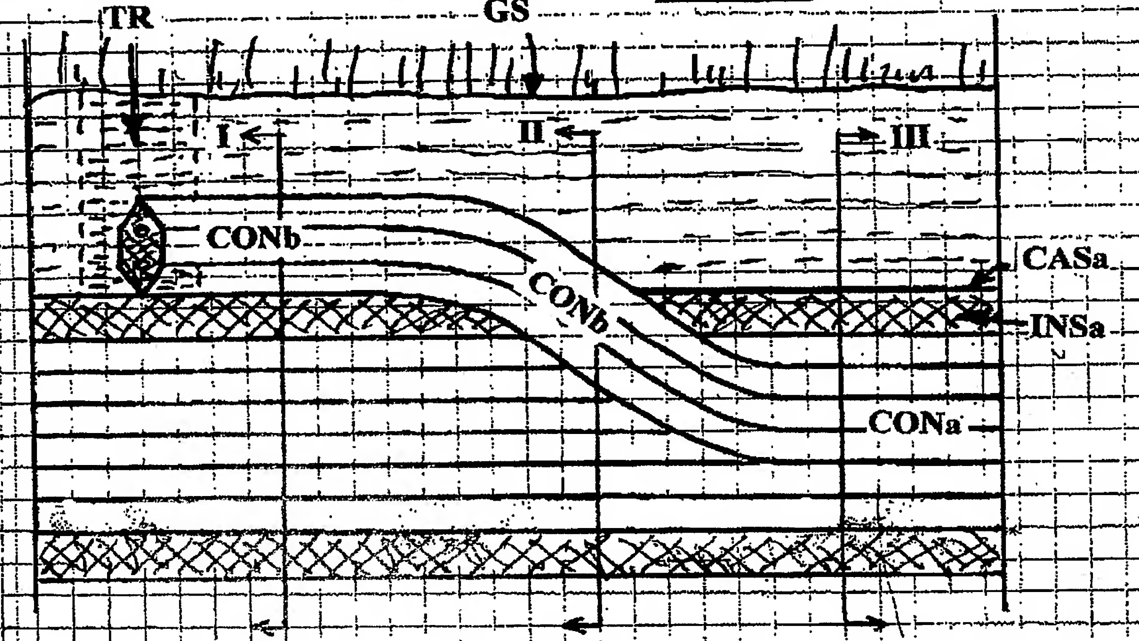


Fig. 13a

Fig. 13b

Fig. 14

Fig. 15



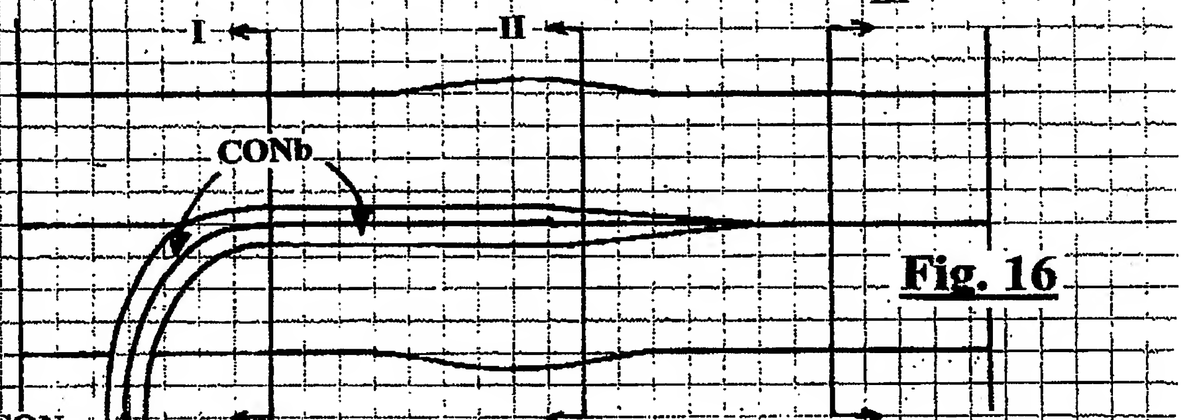


Fig. 16

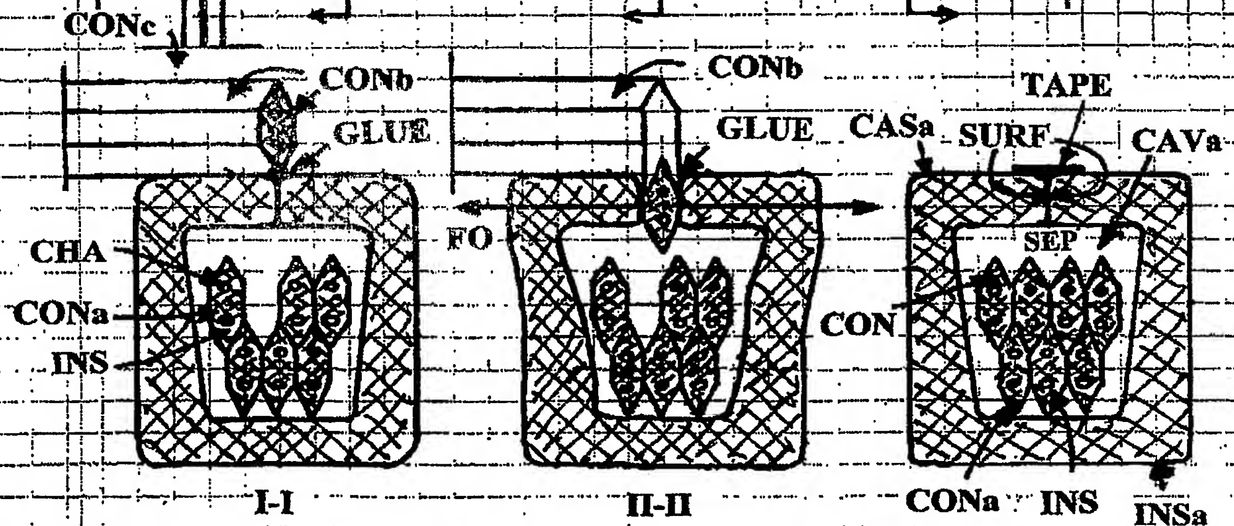


Fig. 17a

Fig. 17b

Fig. 17c